Minnkota Power
MPC COOPERATIVE, INC.
Your Touchstone Energy® Partner

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May 8, 2008

Terry O'Clair
Director, Division of Air Quality
North Dakota Department of Health
918 East Divide Avenue, 2nd Floor
Bismarck, North Dakota 58501-1947

Re: Consent Decree – July 27, 2006
Minnkota Power Cooperative, Inc., et al
U.S. District Court for the District of ND
Civil Action No. 1:06-CV-034

Dear Mr. O'Clair:

Enclosed, please find a report on vendor responses you recently requested from Minnkota. This report, which was prepared by Burns & McDonnell, also includes recent additions and clarifications from vendors. As the report indicates, vendors are not able to make viable guarantees. Additionally, the vendors generally indicate that additional testing would need to be done prior to any design of an SCR for use on a North Dakota lignite-fired cyclone unit.

Should you have any questions, please contact me at jgraves@minnkota.com or 701-795-4221.

Should you have any questions concerning this submittal, please contact me at (701) 795-4221.

Sincerely yours,

MINNKOTA POWER COOPERATIVE, INC.

John T. Graves

John T. Graves, P.E.
Environmental Manager

C: David Sogard w/o encl.
Luther Kvernen w/o encl.
Craig Bleth w/o encl.
Stu Libby w/o encl.
Tom Anseth w/o encl.
Young Station File w/o encl.

MINNKOTA POWER COOPERATIVE, Inc. and
SQUARE BUTTE ELECTRIC COOPERATIVE

ADDITIONAL INFORMATION AND DISCUSSION OF VENDOR RESPONSES ON SCR TECHNICAL FEASIBILITY NORTH DAKOTA'S NOx BACT DETERMINATION for MILTON R. YOUNG STATION UNITS 1 & 2

May 8, 2008

In order to address the issue of vendor guarantees in the NSR Workshop Manual, Burns & McDonnell and Energy & Environmental Research Center (EERC) developed an SCR Vendor Query[1] which was emailed by Burns & McDonnell on April 18, 2007 to selective catalytic reduction (SCR) technology system suppliers and catalyst suppliers. The query requested information from these vendors pertaining to their willingness to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at North Dakota lignite-fired Units 1 and 2 at Minnkota's Milton R. Young Station (MRYS) near Center, North Dakota. Burns & McDonnell described the unit-specific SCR system design conditions and site-specific technical challenges in this query document and its attachments.

This query document (without vendor responses) was originally submitted to the NDDH and EPA as part of an April 18, 2007 response[2] to NDDH's request for information (RFI)[3] regarding their review of the two BACT Analysis Study reports for control of NO_X emissions from existing Unit 1 and Unit 2 at MRYS required by the Consent Decree[4] that were originally submitted to the agencies in October 2006. Additional comments from Region 8 of U.S. EPA[5] were also attached to the NDDH's RFI. A summary of vendor initial responses was initially presented at a meeting of the NDDH, EPA Region 8, and Minnkota on May 23, 2007, in Bismarck by Burns & McDonnell[6].

[1] See Reference number 1, April 18, 2007.
[2] See Reference number 2, April 18, 2007.
[3] See Reference number 3, February 1, 2007.
[4] See Reference number 4, April 24, 2006.
[5] Ibid Reference number 3.
[6] See Reference number 5, May 23, 2007.

In April 2008, Burns & McDonnell became aware that the record on the BACT determination issue for Unit 1 and Unit 2 at MRYS was still open. Due to the fact that one year had passed since the development of the initial SCR Vendor Query document and the vendor responses, Burns & McDonnell initiated contact with several of the vendors in order to more fully understand their initial responses, and to gather additional information.

Appendix A to this document contains emails and letter received from six of the eight SCR technology system suppliers and catalyst suppliers that responded to the referenced original SCR Vendor Query. Subsequently, followup telephone conferences have been held and emails have been exchanged with four of the six companies that responded to the original query. The following are comments pertaining to the SCR vendor's original and followup responses to the April 18, 2007 query.

SCR Vendor Query:

In the referenced April 18, 2007 SCR Vendor Query, Burns & McDonnell requested any information that the SCR system or catalyst supplier could provide regarding the following:

- Detailed information regarding the post-combustion controlled emission rates that full-scale, full-time SCR systems in lignite-fired coal-burning boiler operations have consistently achieved over a period of time, with appropriate pre-controlled baseline emission data.

  That is, Burns & McDonnell requested information that supports a level of emission reductions that could be guaranteed over the course of time, and not merely performance test or limited-duration emissions data, including the following.
  - Data of source-specific boiler and SCR design and operating parameters, along with lignite coal quality characteristics (analytical data) representative of the lignite-fired coal-burning boiler operations associated with long-term post-combustion controlled emission rates that SCR systems have achieved in practice at full-scale installations.
  - If provided, non-full scale laboratory, pilot or bench-scale exposure testing, short-term full-scale compliance or acceptance test data shall be clearly identified as such.

- Definitive statements of expected guaranteed life and control effectiveness performance for SCR catalyst when located in high-dust, hot-side applications at MRYS.

  These statements were requested to be supported by detailed descriptions of the vendor's interpretation of the technical information Burns & McDonnell provided, the vendor's awareness of proven methods of dealing with similar site-specific applications, the vendor's own qualifications and experience, and any stated or assumed design and operational requirements. That is, the guarantee must specifically reference the site-specific operating conditions at MRYS, with an SCR system calibrated to operate in that environment.
- Definitive statements regarding Burns & McDonnell's and EERC's serious concerns involving catalyst blinding and deactivation due to high sodium concentrations along with sulfate and other known components in the flue gas expected from cyclone boilers firing North Dakota lignite.

  Burns & McDonnell provided an analysis of the lignite fuel fired at MRYS, and asked that the guarantee specifically discuss the impact of this particular fuel on SCR system and catalyst performance and longevity.
- A detailed description of the vendor's approach to mitigating Minnkota's risks of failure to meet NO_X emissions control requirements and catalyst activity versus life guarantees, stating what the vendor would do to improve the probability of success prior to initial operation, and how they would respond if the emission control effectiveness and catalyst activity did not match the expectations of the guarantee.

It was understood that the vendor was expected to make certain assumptions regarding SCR system design operating conditions, because detailed development of MRYS unit-specific design schemes to deal with the high boiler outlet flue gas temperatures and other conditions resulting from operation of these cyclone boilers firing North Dakota lignite have not been confirmed. Recognizing that such SCR design details were not currently available, SCR system and catalyst vendors were requested to review the technical information Burns & McDonnell provided. This data was offered as a supplement to the vendors' own technical knowledge, commercial experience, and proprietary data to aid in the understanding of technical feasibility of installing and successfully operating and maintaining currently-available coal-fired SCR system technology on the referenced North Dakota lignite-fired cyclone boilers.

The SCR vendors were also advised of the background of the Consent Decree and BACT Analysis that included Selective Catalytic Reduction (SCR) technology for the Milton R. Young Station. They were made aware that the EPA had issued comments regarding the agency's reviews of the NO_X BACT Analyses. A basic issue to be resolved in order to address the EPA's comments was stated as:

- Would continuous exposure of available high-dust SCR catalyst to current flue gas temperatures and flyash with high sodium concentrations along with sulfate and other known components in the flue gas expected from MRYS cyclone boilers cause severe catalyst fouling, deactivation, and degradation resulting in unacceptable long-term NO_X emission control effectiveness, catalyst life, and cost-effectiveness?

The SCR system and catalyst vendors were asked to consider the current operating conditions and identify solutions to address boiler outlet flue gas temperatures and other conditions resulting from operation of these cyclone boilers firing North Dakota lignite. Vendor responses also needed to consider historic MRYS boiler outlet flue gas temperature data provided with the query that showed wide variations with boiler fireside cleanliness and load.

Comments on SCR Vendor Query Responses:

Information requests via email were sent to four SCR system vendors and four catalyst vendors[7]. Two of the original eight SCR system vendors and catalyst vendors (Argillon and Cormetech) indicated they would provide a response but subsequently did not, even after further followup. Six of the eight vendors did provide information: Alstom Power Environment, Babcock & Wilcox, Babcock Power Environmental, Ceram, Haldor Topsoe, and Hitachi.

[7] See Reference number 6, April 18, 2007.

None of the vendors provided all of the information requested. The initial vendor responses that were unclear or provided information appearing to be stated without substantive basis or backup with identified source data were targeted for followup and telephone conference. The following includes comments by Burns & McDonnell (and EERC where so indicated) regarding the initial individual vendor responses from May 2007, and the subsequent supplemental responses following the late April 2008 telephone conference calls.

Summary of Alstom Power's Responses and 2008 Followup:
Alstom Power's initial response was provided in a letter dated May 30, 2007[8] submitted via email. Their initial comments provided information on lignite-fired boiler SCR applications, alternative tail-end SCR, predicted SCR performance, and indicative pricing and delivery for conventional SCR technology.

Alstom confirmed that there have not been any SCRs applied to boilers in the United States firing North Dakota or Texas lignites. Experience with an in-situ mini SCR reactor installed at TXU Energy's Martin Lake Unit 3, tested with two types of catalyst, was not detailed. Alstom recognized that North Dakota lignite is higher in sodium than Texas lignite, but stated that fuels high in sodium and potassium can be treated with specially selected catalyst. Wood and biomass-fired European boilers equipped with a hot-side electrostatic precipitators (ESPs) were cited as examples of dealing effectively with these catalyst poisons in such hot-side SCR applications.

Alstom expects acceptable emissions control and maintenance requirements can be achieved on North Dakota lignite service, assuming that the SCR system operates between 600-750°F. They anticipate that a modification or replacement of the economizer will be required to control boiler flue gas temperature within an acceptable range.

A Tail End SCR was mentioned as an alternative solution, with advantages and disadvantages briefly described. No plants firing fuels similar to North Dakota lignite with a Tail End SCR were identified.

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[8] See Reference number 7, included in Appendix A, dated May 30, 2007.

Alstom predicts that a properly designed SCR (presumably on a boiler firing North Dakota lignite) should be capable of achieving up to 90% [NO_X] removal efficiency with 2 ppm ammonia slip. They acknowledge minimal field data to predict how often the catalyst would need to be replaced, with 16,000 hours between replacements as a suggested average based on lab results.

Indicative pricing for materials and labor to provide conventional SCR technology at MRYS was stated, absent detailed analysis and without potential additional scope because of unusual design requirements to deal with the boiler flue temperatures and catalyst contaminants.

<u>Alstom's April 28, 2008 Telephone Conference Call and Followup Response</u>:

Alstom could not offer any new or different information that agrees with or refutes information presented in the October 2005 EERC report of slipstream catalyst testing at Coyote Unit 1 referenced in the SCR vendor query. Alstom acknowledged that "there are no known existing applications of SCR to ND lignite fired boilers, therefore there is some risk on any first [of] a kind application". Alstom's May 2008 letter also states:

> "Application of a traditional SCR to Lignite fired units will require some R&D, custom engineering, and likely a pilot testing program. This will be time consuming and expensive but will reduce the risks involved in a new application such as this one".

Alstom indicated its belief that Tail End SCR downstream of a hot-side ESP would be immune to catalyst poisoning from sodium-potassium-sulfur compounds. They agree that biomass and wood-fired boiler SCR experience with low sulfur is not the same situation as cyclone boilers firing North Dakota lignite.

Based on current data, Alstom indicated that they cannot guarantee SCR system performance for MRYS boilers firing North Dakota lignite because it hasn't been installed full-scale on a boiler firing this fuel. Additional pilot-testing of at least one year would be needed.[9]

[9] See Reference number 8, included in Appendix A, dated May 5, 2008.

Comments on Alstom Power's Responses and April 28, 2008 Telephone Conference Call:
Alstom did not provide detailed information completely responsive to all aspects of the subject raised in the original SCR Vendor query. Sources of field and laboratory test results of catalyst were cited but not substantiated with actual technical references or submittal of data.
An Alstom representative involved with Alstom's initial and followup responses (John Buschmann) acknowledged familiarity with the October 2005 EERC report of the SCR catalyst pilot testing at Coyote station.

Alstom did not appear to fully recognize how the method of firing the fuel in a cyclone boiler alters the character and composition of the flyash exhausted from the boiler, and that such contaminants pass through high-efficiency air cleaning equipment and create deposits that can blind and plug catalyst. The temperature of cyclone firing is higher and causes more vaporization of sodium and potassium in the lignite ash than occurs with a wood-fired boiler system. The wood-fired boiler systems have lower flame temperatures and thus less vaporization of alkali elements. This is evident based on the abundance of sodium and potassium-rich particles in the small ash size fraction found in the Coyote pilot SCR test catalyst and the particulate filter described in the referenced SCR vendor query. The sodium and potassium-rich materials combine with sulfur species to form sulfates that are significantly different and more problematic in their impacts on catalyst than Alstom's wood-fired boiler SCR experience indicates.

Alstom's wood-fired boiler SCR experience is not closely comparable to North Dakota lignite firing in cyclone boilers at MRYS. In general, alkali content of fly ash from wood firing is similar to the alkali content in the fly ash from the cyclones firing Center lignite. However, the form of the alkali in fly ash from the lignite-fired cyclone is likely in the oxide/hydroxide and partially sulfated forms; in wood fly ash, it will take another form, such as a chloride, if available. The lignite cyclone combustion derived alkali species are highly reactive with sulfur oxides resulting in the formation of a cohesive ash that produce stronger bonds and fill and coat catalyst pores and surfaces.

Alstom appeared to be unfamiliar with the unique high temperature air and flue gas requirements associated with the lignite drying systems on these MRYS boilers. Their expectation that a boiler economizer modification or replacement would resolve the low load-clean boiler-low flue gas temperature and high load-dirty boiler-high flue gas temperature situation appears to be a gross assumption based on an incomplete understanding of the thermodynamics of the flue gas, air, and fuel treatment systems employed at this facility[10].

No offer of any kind of SCR performance or service life guarantee was made by Alstom. The 16,000 hours between replacements, suggested as an average based on lab results[11], is not a guarantee or warranty, and was stated without the source data of the laboratory tests.

Summary of Argillon's Responses:

Argillon acknowledged the initial emailed query but failed to provide an actual initial response via phone call or email.[12]

Summary of Babcock & Wilcox's Responses:

Babcock & Wilcox did not provide detailed information completely responsive to all aspects of the subject raised in the original SCR Vendor query. Babcock & Wilcox's initial response via email[13] confirmed that there is not any full-scale operational experience with SCR systems retrofit to boilers firing North Dakota lignite or any other type of lignite in the United States. Therefore, neither B&W nor any other SCR system supplier can "provide detailed information regarding the post-combustion controlled emissions rates that full-scale, full-time SCR systems in lignite-fired coal-burning boiler operations have consistently achieved over a period of time."

B&W agrees with Burns & McDonnell that there are significant challenges associated with both boiler operation (high economizer exit gas temperature) and lignite firing (flue gas constituents) at Milton R. Young Station (MRYS). They mentioned the lack of justification and the need to invest significant dollars in research and development efforts to fully

[10] See Reference number 9.
[11] Ibid Reference number 7, included in Appendix A, dated May 30, 2007.
[12] See Reference number 10, included in Appendix A.
[13] See Reference number 11, included in Appendix A.

investigate and understand both technical and commercial risks involved with applying SCRs on a limited number of units firing North Dakota lignites.

B&W has not fully explored the issues presented in the SCR vendor query with catalyst suppliers to better understand and quantify these challenges, or what may be needed to identify their concerns or the lengths to which they may need to go to address them especially if catalyst guarantees must be offered.

No offer of any kind of SCR performance or service life guarantee was made by B&W.

<u>Summary of Babcock Power's Responses and 2008 Followup</u>:

Babcock Power Environmental's (BPE's) initial response[14] recognized that "there have been a few tests performed to ascertain the possibility of using a high dust SCR on lignite and the potential for fouling/poisoning of the catalyst has been in question". BPE also indicated an expectation that "an SCR system could be successfully utilized on a boiler fired with Northern lignite fuel", while recognizing uncertainty regarding the ability of a high dust SCR on a boiler firing North Dakota lignite because there has not been any testing or installation of an SCR reactor of any significant size on such a boiler. BPE also "identified the MY1 and MY2 boilers as a very difficult one on which a high dust SCR would be applied because of the unique configuration of the boiler and the wide temperature swings that are encountered".

BPE indicated that "several possible solutions exist with varying certainties of outcome. The SCR technology location may potentially mitigate the issues with the possible poisoning of the catalyst by constituents in the gas from the combustion of Northern lignite". Babcock Power recommended that "an engineering study be conducted to evaluate three key issues":

- Initial estimates of the actual deactivation of SCR catalyst in the high dust location by the use of coupons positioned in the hot gas stream downstream of the economizer.
- Initial estimates of the actual deactivation of SCR catalyst in other locations by the use of coupons positioned in the gas stream downstream of the airheater.

[14] See Reference number 12, included in Appendix A.

- Possibility of a retrofit of an SCR into the MY1 and MY2 boiler considering the wide range of temperature for the flue gas and possible boiler modifications required.

Comments on Babcock Power's Responses and April 28, 2008 Telephone Conference Call: Babcock Power Environmental did not provide detailed information completely responsive to all aspects of the subject raised in the original SCR Vendor query. BPE's original email statements seem to be based upon the vendor's experience with other lignite fuels not specifically identified by location or composition. Subsequent email[15] and telephone[16] followup in 2008 indicated that the use of high activity SCR catalyst coupons positioned in the hot gas stream downstream of the boiler economizer, would also include test locations downstream of the existing cold-side electrostatic precipitator (and in Unit 2's case, a wet lime/flyash scrubber). BPE considers this a kind of "fatal flaw" investigation that would be conducted first. This would allow BPE to analyze the test catalyst coupons for deactivation to see if a high-dust SCR location could work. This initial testing would be conducted without ammonia reagent being injected into the flue gas stream ahead of the test catalyst. If BPE determined that there was potential for SCR success after analyzing the test catalyst coupons, a test reactor of appropriate size would be designed and built and installed. BPE indicated that such a test SCR reactor would need to be operated for a minimum of 4000 hours.

A Babcock Power Environmental representative involved with BPE's initial and followup responses (Clay Erickson) appears to be familiar with the October 2005 EERC report of the SCR catalyst pilot testing at Coyote station. BPEI's second emailed response stated that they have not nor know of any further work on this topic since the response they previously provided via email on May 11th 2007[17].

No offer of any kind of SCR performance or service life guarantee was initially made by Babcock Power Environmental. BPE would not guarantee performance unless the catalyst vendors would provide such a guarantee[18]. Furthermore, BPE indicated that it would not

[15] See Reference number 13, included in Appendix A.
[16] See Reference number 14.
[17] Ibid Reference number 13, included in Appendix A.
[18] Ibid Reference number 14.

provide a guarantee of SCR performance on this fuel at these units without additional data such as that which would be derived from the test reactor described above[19].

Summary of Ceram's Responses and 2008 Followup:

Ceram reviewed the information provided by Burns & McDonnell regarding the technical feasibility of SCR on the Milton R. Young Station Units 1 and 2 firing North Dakota Lignite fuel[20]. Ceram's initial response comments acknowledged the lack of any catalyst installations currently operating with North Dakota lignite fuel. One brown coal SCR installation (not specifically identified) in Europe, and a large experience base with coals, refineries and incinerators combined with familiarity with the effects of a wide range of fuel and flue gas constituents was mentioned. They indicated that their brown coal from Europe was more like a Texas lignite ash. They indicated that sodium is a concern since it has a potential to infiltrate into the catalyst and cause deactivation especially during heat-up and cool-down. They were not familiar with cyclone firing and enhancement of sodium in the fines[21].

Ceram initially noted that North Dakota Lignite fuel and ash characteristics present certain challenges related to SCR operation and reliability. Additionally, the high flue gas temperatures needed for purposes of drying the fuel were mentioned as a challenge for SCR catalyst design, but no specific solution to this situation other than "flue gas tempering" being required was proposed.

Ceram's initial comments pertinent for this SCR application largely included items that needed to be considered or included in the SCR catalyst selection and reactor design, such as the presence of pyrosulfates (sodium, iron and sulfur) having the potential to increase the oxidation of sulfur (SO_2 to SO_3 conversion rate). Ceram could only guarantee the initial SO_2 to SO_3 conversion rate and not the end of life conversion rate.

Ceram provided a preliminary catalyst design that utilized a 7.4 mm pitch catalyst to minimize the risk of catalyst pluggage due to high concentrations of calcium and sulfates in the fuel. A

[19] Ibid Reference number 14.
[20] See Reference number 15, included in Appendix A.
[21] See Reference number 16.

full SCR bypass system with an air drying or dehumidification system was recommended to keep the catalyst warm and dry during lay-up periods because of the high sodium and iron concentrations. The maximum continuous operating temperature of the preliminary SCR catalyst design was 850° F, with an allowance of short periods of operation up to 900 degrees F. A high temperature reference list of Ceram's SCR catalyst installations was provided.

Ceram developed a preliminary catalyst design for each Unit (outlined in attached files) that were expected to provide 85% NOx reduction (0.08 lb/MBtu outlet) with an SO_2 to SO_3 conversion rate of 1.0% and ammonia slip of 2.0 ppm for a guarantee life of 16,000 hours.

A Ceram representative involved with Ceram's initial response (Noel Rosha) acknowledged he was unfamiliar with the October 2005 EERC report of the SCR catalyst pilot testing at Coyote station[22]. After the April 23, 2008 telephone conference call, Ceram obtained a copy of the referenced October 2005 EERC report. The Ceram representative responding to the followup request (John Cochran) after reviewing EERC's report believed it was "certainly premature to assume that there is a fatal flaw for the use of high dust SCR behind cyclones burning North Dakota lignite". Also, Ceram stated: "Certainly a number of circumstances are present that necessitate a pragmatic approach to the application of catalyst for a lignite application" and "Sodium is not a poison to catalyst at SCR operating temperatures. Significant deactivation can occur if condensed moisture transports sodium residing at the surface into the catalyst pore structure during outage or layup"[23].

Ceram's second emailed response included Ceram's reasons for why it believes the application of SCR technology on North Dakota lignite-fired cyclone boilers can be successful. Ceram also advised that "in no event would any ammonia be allowed to be injected below 530 F for any likely combination of reasonable sulfur and NOx removal parameters. The NOx reduction for a reduced MOT [minimum operating temperature] should be considered in 30-day rolling average scenarios. Minimum flue gas temperatures listed for Units 1 and 2 are well below this threshold"[24].

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[22] Ibid Reference number 16.
[23] See Reference number 17, included in Appendix A.
[24] Ibid Reference number 17.

Ceram also included the following statement in their followup response: "based on the information provided as well as our large foundation of work related to the fuel considerations noted in the query and study CERAM can provide a commercial offering regarding this project. However, considering some of the remaining uncertainties we would recommend further testing to ensure a successful result"[25].

Comments on Ceram's Responses and April 23, 2008 Telephone Conference Call:
Ceram did not provide detailed information completely responsive to all aspects of the subject raised in the original SCR Vendor query. Their comments mentioned high sodium contents and fine fume as concerns reported by Dr. Benson and the EERC report on slipstream pilot SCR testing having "flawed pitch and resultant pluggage of the catalyst used during Coyote Station testing" as "inadequate evidence ... that this could be a fatal flaw to application of SCR"[26].

What appears to be missing from Ceram's comments are recognition that North Dakota lignite firing in cyclones promotes formation of low melting point eutectic combinations of sodium, potassium, and sulfur to form sulfates which produce extremely strong deposits that fill and plug the pores of the catalyst, regardless of the pitch. The effects of this eutectic melting and blinding was not considered, as Ceram's comments focus on the issue of significant deactivation from sodium due to mobilization of sodium if condensed moisture becomes available.

Ceram's initial response mentions a guaranteed catalyst service life of 16,000 hours and the initial SO_2 to SO_3 conversion rate, but did not actually expressly state that they would guarantee NOx reduction performance. Their willingness to provide a commercial offering is based upon recommended "further testing to ensure a successful result"[27].

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[25] Ibid Reference number 17.
[26] Ibid Reference number 17.
[27] Ibid Reference number 17.

Summary of Cormetech's Response:

Cormetech acknowledged the initial emailed query but failed to provide an actual initial response via phone call or email.[28]

Summary of Haldor Topsoe's Responses and 2008 Followup:

After its initial review of information and data provided by Burns & McDonnell regarding the viability of SCR technology on the Milton R. Young Station (MRYS) Units 1&2, Haldor Topsoe (HT) indicated that two separate issues exist with this application: extremely high flue gas exit temperatures (FGET) and lack of flue gas temperature control over the long term; and fuel-related issues specific to this variety of North Dakota lignite[29]. Haldor Topsoe did not address the high FGET as a unit-specific problem, presumably because they are not boiler heat transfer solution providers. HT indicated that they don't have a catalyst for coal-fired boiler applications that will survive 900°F flue gas that can be offered with a guarantee[30].

Based on the provided fuel and ash analysis of the North Dakota lignite that is burned at MRYS, Haldor Topsoe estimates that the deactivation rate of the catalyst will be high but manageable. A deactivation rate in line with wood-fired boilers which have been successfully fitted with SCR was predicted in HT's initial response; now, HT states this rate is higher than what they have seen on wood-fired boilers[31]. HT initially expected the deactivation rate to be steep initially but to flatten out considerably after about 4000 hours, and has recently (May 2008) modified this estimated time frame to 10,000 hours, where the catalyst is expected to lose about 60 percent of its initial activity during this time period. HT stated that the revised deactivation rate number is based mostly on comparison of the expected catalyst service conditions compared to that of wood-fired boilers. Higher flyash loading and catalyst attrition, combined with much more sulfur that leads to blinding of the catalyst were briefly described[32].

[28] See Reference number 18, included in Appendix A.
[29] See Reference number 19, included in Appendix A.
[30] See Reference number 20.
[31] See Reference number 21, included in Appendix A.
[32] Ibid Reference number 21, included in Appendix A.

HT originally stated that the expected catalyst poisons are mostly water soluble, therefore periodic water washing of the catalyst can be used to regain activity and to increase overall service life. This technique is used on many wood and some PRB coal-fired applications.

Besides the deactivation, Haldor Topsoe identified another catalyst impact problem: clogging[33]. Ineffective sootblower simulation in the Coyote pilot test was the primary concern/experience, which HT infers does not represent full-scale SCR installations.

HT suggests that the next step is to install a larger pilot scale experiment with cross section of catalyst on the order of 2 meters by 2 meters. This would allow better catalyst cleaning and give a better determination of the catalyst degradation over time[34].

Based on the fuel analysis provided to HT and assuming that FGET can be controlled, HT would be willing to guarantee SCR catalyst performance on these units[35]. Haldor Topsoe expects 60 percent deactivation over the first 10,000 operating hours. HT can not provide a "make good" guarantee, but is willing to warrant their catalyst performance up to the contract value[36].

A subsequent email dated May 7, 2008 from Dr. Joakim Thøgersen of Haldor Topsoe (Denmark) to Robert Blakley to address additional followup questions to Flemming Hansen's May 5, 2008 email response provided further information regarding the wood-fired boiler SCR experience versus a hypothetical North Dakota cyclone boiler SCR situation[37].

One issue was the difference in flyash loading between ND lignite-fired cyclone boilers and wood-fired boilers mentioned previously by HT. The fly ash concentration in lignite flue gas is 5-10 times higher than in wood-fired boiler flue gas. But the fraction of alkali in flyash that deposits in the catalyst is a much smaller portion of the total flyash loading in lignite flue gas than wood-fired boilers. The reason according to Dr. Thøgersen has to do with the alkali being

[33] Ibid Reference number 21, included in Appendix A.
[34] Ibid Reference number 21, included in Appendix A.
[35] Ibid Reference number 19, included in Appendix A.
[36] Ibid Reference number 21, included in Appendix A.
[37] See Reference number 22, included in Appendix A.

bound in coarse aluminum/silicate fly ash particles that don't contribute to the deposits in the catalyst to the same extent. When the alkali is incorporated in aluminum/silicate fly ash, the alkali also becomes inactive as a SCR poison. The lignite fly ash also has a cleaning effect by attrition of the surface that causes re-entrainment of particle deposits. Attrition is re-entrainment or cleaning of the catalyst surface by particle impaction[38].

Another issue was the much higher concentration of sulfur in ND lignite cyclone boiler flue gas compared to wood-fired boiler flue gas. Haldor Topsoe recognizes that SO_2 levels in ND lignite flue gas are 700-800 ppm whereas it is less than 10 ppm in wood flue gas. The sulfur leads to a strengthening and densification of the blinding layers that originates from deposition of calcium, sodium, and potassium aerosols[39]. The sulfur reacts with deposited sodium chloride (NaCl), calcium oxide (CaO), and potassium chloride (KCl), which means that the particles swell and the blinding layer becomes more impermeable[40].

A telephone conversation between Dr. Joakim Thøgersen and Steve Benson on May 2, 2008 indicated that the deactivation rates would be greater than that of the worst wood-fired system because of the high sodium and sulfur (greater than 60% in 10,000 hours). Dr. Thøgersen indicated that at this point, Haldor Topsoe would not be in a position to make a 100% "make good" guarantee[41]. Haldor Topsoe's predictions of SCR catalyst deactivation are somewhat semi quantitative since the predictions are based on extrapolation/interpolation from wood firing and PRB fired boilers[42].

<u>Comments on Haldor Topsoe's Responses and April 24, 2008 Telephone Conference Call</u>: Haldor Topsoe (HT) did not provide detailed information completely responsive to all aspects of the subject raised in the original SCR Vendor query. Sources of catalyst experience on wood-fired boilers were cited but not substantiated with actual technical references or submittal of data.

[38] Ibid Reference number 22, included in Appendix A.
[39] Ibid Reference number 21, included in Appendix A.
[40] Ibid Reference number 22, included in Appendix A.
[41] See Reference number 23.
[42] Ibid Reference number 22, included in Appendix A.

The Haldor Topsoe representative involved with their initial response (Wayne Jones) acknowledged he was unfamiliar with the October 2005 EERC report of the SCR catalyst pilot testing at Coyote station[43]. Flemming Hansen provided the followup response, and was a participant in the referenced Coyote Station SCR catalyst pilot testing.

The amount and basis of HT's initial estimate of 4000 hours for rapid catalyst deactivation when exposed to North Dakota lignite-fired cyclone boiler flue gas and flyash was not provided, only that it was originally of the same magnitude as wood-fired boiler SCRs[44]. Now the expectation is stated to be worse than wood-fired boiler SCRs, with 60% deactivation over the first 10,000 operating hours[45].

Haldor Topsoe' apparent initial willingness to guarantee SCR catalyst performance on Unit 1 and Unit 2 at Milton R. Young Station firing North Dakota lignite is based largely on their experience on boilers firing wood with SCRs that have 5 to 10 times less flyash and 70 to 80 times less sulfur[46]. It also requires that the high flue gas temperatures presented in the query document are lowered and controlled, without knowing if or how this might be accomplished.

Haldor Topsoe's wood-fired boiler SCR experience is not closely comparable to North Dakota lignite firing in cyclone boilers at MRYS. In general, alkali content of fly ash from wood firing is similar to the alkali content in the fly ash from Center lignite. However, the form of the alkali in fly ash from cyclone-fired lignite is an oxide/hydroxide and sulfate; in wood fly ash, it will take another form, such as a chloride, if available. There are differences in reactivity between these forms of alkali with sulfur oxides that make the lignite flyash produce stronger bonded deposits on catalyst surfaces and in pores.

The temperature of cyclone firing is higher and causes more vaporization of alkali elements in the lignite ash than occurs with a wood-fired boiler system. The wood-fired boiler systems have lower flame temperatures and thus less vaporization of alkali elements. This is evident

[43] See Reference number 24.
[44] Ibid Reference number 19, included in Appendix A.
[45] Ibid Reference number 21, included in Appendix A.
[46] Ibid Reference number 21, included in Appendix A

based on the abundance of sodium and potassium-rich particles in the small ash size fraction found in the Coyote pilot SCR test catalyst and the particulate filter described in the referenced SCR vendor query. The sodium and potassium-rich materials combine with sulfur species to form sulfates are significantly different and more problematic in their impacts on catalyst than HT's wood-fired boiler SCR experience.

The pathway to the formation of bonded deposits on catalyst surfaces and pores for wood firing is different in lignite fired systems. HT suggested sodium chloride (NaCl) and potassium chloride (KCl) along with calcium oxide (CaO) are the intermediate species that become sulfated for the lignite application. It is evident that HT bases their assumptions on wood firing. In lignite, the intermediate species differ from wood because of the low levels of chlorine in the lignite coal. The reactions for sodium and potassium likely follow the path from vaporized atomic sodium and potassium in the flame to condensed sodium and potassium oxides or hydroxides. The calcium oxide (CaO) particles will form on the surface of the burning char particles and will be released as the char burns out. This resulting mixture (Na_2O/NaOH, K_2O/KOH, and CaO) of small particles (aerosols) will undergo minor sulfation during entrainment. As the particles are being transported with the bulk gas flow through the catalyst, they will deposit in the pores and on the surface of the catalyst. Once deposited, the particles will react with SO_3 to form sulfates and pyrosulfates causing the particles to swell filling pores and creating an impermeable layer. Another key point is that the rate of reaction to form sulfate is very fast in the pores because of the ability of the catalyst to convert SO_2 to SO_3.

Regarding the differences between ND lignite-fired cyclone boilers and wood-fired boilers mentioned previously by HT, loadings of ash are presumably higher for Center lignite and the potential for the scrubbing action of the silicate materials is possible. However, this scrubbing action will be unlikely for operations firing lignite with high sodium-low ash combinations supplied from the Center mine. In the low ash cases of ND lignite from the Center mine, the sulfated sodium and calcium particles are highly cohesive because of sulfate/pyrosulfate bonding that occurs between the particles. These types of bonded phases will be resistant to attrition and sulfate/pyrosulfate materials will capture the silicate particles resulting in increased growth and plugging. The scanning electron microscope (SEM) images in the October 2005 EERC paper[47] show evidence of captured aluminosilicate particles bonded in a sodium calcium sulfate matrix. The attrition effect described by Dr. Thøgersen assumes that erosion of the deposited materials will take place subsequent to particle impaction. However, if the deposit on the catalyst surface is cohesive and sticky, deposit growth will take place as described above.

Summary of Hitachi's Response:

Hitachi did not provide detailed information completely responsive to all aspects of the subject raised in the original SCR Vendor query. Hitachi's initial response via email[48] confirmed that there has been very little testing and data available on North Dakota lignite. After their initial review of information and data provided by Burns & McDonnell regarding the viability of SCR technology on the Milton R. Young Station (MRYS) Units 1&2, Hitachi expressed several concerns about the difficulty of installing and operating a hot-side, high-dust SCR:

- Without a plan to reduce the flue gas temperature, the catalyst will deactivate very quickly above 850 degrees F.
- High sodium content of the ash may cause serious deactivation of the catalyst.
- High sulfur trioxide (SO_3) content in ash may also cause faster catalyst deactivation.
- Sticky ash will cause a pluggage problem.

Because of all these unknowns, Hitachi strongly recommended that a slipstream test be performed to confirm the applicability of the catalyst for this flue gas[49].

Summary Comments on SCR System Suppliers' and Catalyst Suppliers' Responses:

The responses were mixed, with the SCR System Suppliers (boiler original equipment manufacturers) being pessimistic (B&W, Hitachi) to optimistic (Alstom, BPE) about the ability of an SCR system to be successful on these cyclone boilers burning North Dakota lignite. The SCR Catalyst Suppliers that provided technical responses (Ceram, Haldor Topsoe, and Hitachi) were mixed in their response, with Ceram and HT being more positive and Hitachi more

[47] See Reference number 25.
[48] See Reference number 26, included in Appendix A.
[49] Ibid Reference number 26, included in Appendix A.

negative. Of the catalyst vendors that were favorable, both indicated that their willingness to offer performance guarantees requires solving the flue gas temperature problems for which they are not responsible. Haldor Topsoe further qualified their willingness to warrant their catalyst performance was not a "make good" guarantee, but is limited to the amount of contract value of supplying the catalyst, which is a small portion of a typical full-scale full-time SCR system installation. Ceram did not specify their catalyst performance guarantee nor service life warranty limits. None of the SCR system suppliers offered any performance guarantees, not even Alstom and Babcock Power who believe that SCRs could be successfully utilized on MRYS cyclone boilers firing North Dakota lignite.

SCR suppliers and catalyst suppliers did not provide detailed information completely responsive to all aspects of the subject raised in the original SCR Vendor query. Some responses were more detailed than others; none included reference plant information or specific fuel and ash analysis data that presumably forms the basis of their opinions, estimates and predictions.

The vendors did not offer any new or different field pilot testing or laboratory/bench scale information including catalyst analysis from samples exposed to flue gas and flyash created from firing North Dakota lignite that agrees with or refutes information presented in the October 2005 EERC report of slipstream catalyst testing at Coyote Unit 1 referenced in the SCR vendor query. Several acknowledged that there are no known existing applications of full-scale, full-time SCR technology to ND lignite fired boiler, therefore there is some risk in this application. Suppliers did not provide much detail in identifying solutions to mitigate risks; mostly their comments suggested or recommended various tail-end SCR or low-dust SCR configurations to minimize flyash deposition. These responses largely ignored the evidence presented in the April 2007 query and October 2005 EERC report that fine alkali particles pass though the dust collection equipment (ESPs) that would be located ahead of these SCR reactors, which will plug pores and blind the catalyst surfaces, making the catalyst ineffective in reducing NOx emissions.

Of the SCR suppliers and catalyst suppliers providing additional responses, all recommend or favor a course of further research and pilot-scale testing before they would be confident of catalyst deactivation rates, service life, location in the gas stream for placement of the SCR reactor, and amount of catalyst required.

Conclusions on SCR Technical Feasibility for North Dakota's BACT Determination:

Minnkota has previously submitted arguments regarding the appropriateness of conducting pilot testing of selective catalytic reduction (SCR) technology at Milton R. Young Station Units 1 and 2 for use in a NOx BACT Analysis[50]. The vendor responses summarized and included herein have not altered the rationale of Minnkota's arguments that:

- Pilot-scale testing of SCR technology is specifically not required by the BACT determination procedures established by the U.S. Environmental Protection Agency (EPA).
- Previous research, including previous SCR pilot testing conducted at Coyote Station[51], indicates that there is not sufficient reason to believe that additional pilot testing suggested by SCR system suppliers and catalyst suppliers will produce results substantially different than those obtained from the prior pilot test.

Vendor responses to an SCR Vendor Query[53] did not adequately address guarantees and warranty of system performance and catalyst service life to mitigate potentially significant, long-term operational and financial risks based on the specific applications involved. This query sought information that forms the basis of the vendors' responses to the issue of guarantees, including:

- Whether such guarantees would satisfy a "make good" requirement;
- Would the vendor provide a catalyst service life guarantee and replacement warranty; and

[50] See Reference number 27.
[51] Ibid Reference number 25.
[53] Ibid Reference number 1, April 18, 2007.

- Whether any catalyst service life that a vendor would propose is based on the special nature of this fuel and ash composition method of firing (in a cyclone) and the location relative to gas cleaning equipment.

All vendors that responded to the query mentioned the significant challenges involved with the design considerations for applying SCR technology to these MRYS boilers. Only two vendors provided responses that included willingness to offer any guarantees on catalyst performance, with significant limitations on acceptable operating conditions which are yet to be achieved and would require solutions provided by other vendors. One of these catalyst suppliers responded that they would not be willing to offer a "make good" guarantee. The lack of suppliers' willingness to extend system and catalyst performance guarantees that satisfy "make good" requirements, as well as a lack of detail on service life warranty offers, does not support a substantial endorsement of applying SCR technology to these MRYS boilers with sufficient guarantees and certainty of results without having to perform substantial pilot testing, research and development, and specialized design as provided in the vendor responses.

Minnkota has previously presented the regulatory basis for the decision to not conduct pilot testing, as well as the reasons for technical infeasibility of SCR technology, for use in a NOx BACT Analysis[54]. The significant limitations stated by the catalyst suppliers regarding acceptable operating conditions which are yet to be attained and would require solutions provided by other vendors are significant caveats to believe that any suggested guarantees on catalyst performance or service life would be achieved with certainty. The fact that all the SCR suppliers responding to query recommend or favor pilot testing means that this technology is insufficiently developed to be considered "available" for the Unit 1 and Unit 2 boilers at MRYS burning North Dakota lignite as discussed in the EPA's NSR Manual[55].

Minnkota has provided sufficient information and documentation to NDDH and EPA, including responses to issues raised and requests made after submittal of the BACT Analysis Study reports[56] in October, 2006, to establish that SCR cannot be reasonably installed and

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[54] Ibid Reference number 27.
[55] See Reference number 28,
[56] See Reference number 29, October, 2006,

operated on the cyclone-fired boilers burning North Dakota lignite located at Milton R. Young Station.

REFERENCES

1 Burns & McDonnell and Energy & Environmental Research Center (EERC), *"Information Request"* (SCR Vendor Query and Attachments), April 2007.

2 Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative "*Responses To NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns, Milton R. Young Station Unit 1 And Unit 2 NOx BACT Analysis Study, April 18, 2007*".

3 North Dakota Department of Health, Environmental Health Section, Division of Air Quality letter by Terry L. O'Clair, P.E. to John Graves, Minnkota Power Cooperative, *Re: BACT Determination Milton R. Young Station*, dated February 1, 2007, with enclosure from United States Environmental Protection Agency Region 8, letter to Terry O'Clair, North Dakota Department of Health Division of Air Quality, *Re: Transmittal of EPA Non-SCR concerns and additional information required for Minnkota BACT Analysis Study*, dated January 26, 2007.

4 Consent Decree filed in the United States District Court For The District Of North Dakota, United States Of America and State Of North Dakota, Plaintiffs, v. Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Defendants, Civil Action No.1:06-CV-034, filed April 24, 2006.

5 Burns & McDonnell and Energy & Environmental Research Center (EERC) presentation to North Dakota Department of Health, Environmental Health Section, Division of Air Quality, and United States Environmental Protection Agency, *"Summary of Responses to EPA/DOH Questions on Minnkota Power's NOx BACT Analysis for Milton R. Young Units 1 & 2"*, May 23, 2007.

6 Burns & McDonnell list of SCR System Suppliers and SCR Catalyst Suppliers (for sending SCR Vendor Query Information Request via email), 4/18/2007.

7 Electronic mail, Robert Blakley to Chuck Nordhausen (Alstom Power) April 18, 2007, and Letter (submitted via email), Michael G. Phillips (Alstom Power Environmental Control Systems) to Robert Blakley, May 30, 2007. See Appendix A for copies.

8 Electronic mail, Robert Blakley to John Buschmann (Alstom Power Environmental Control Systems), April 28, 2008; and Letter (submitted via email), Michael G. Phillips (Alstom Power Environmental Control Systems) to Robert Blakley, May 5, 2008. See Appendix A for copies.

9 Personal notes from Telephone Conference, John Buschmann (Alstom Power Environmental Control Systems) with Robert Blakley, Carl Weilert, and Steve Benson (EERC), April 28, 2008.

10 Electronic mail, Robert Blakley to Cindy Khalaf (Argillon) April 18, 2007, and April 19, 2007 email reply. See Appendix A for copies.

11 Electronic mail, Robert Blakley to Steve Moorman (Babcock & Wilcox) April 18, 2007, and May 10, 2007 email reply. See Appendix A for copies.

12 Electronic mail, Robert Blakley to Rich Abrams (Babcock Power Environmental) April 18, 2007, and response email, May 11, 2007. See Appendix A for copies.

13 Electronic mail, Robert Blakley to Clay Erickson (Babcock Power Environmental, April 28, 2008, and response email May 6, 2008. See Appendix A for copies.

14 Personal notes from Telephone Conference, Clay Erickson and Joe Langone (Babcock Power Environmental) with Robert Blakley, Carl Weilert, and Steve Benson (EERC), April 28, 2008.

15 Electronic mail, Robert Blakley to John Cochran (Ceram) April 18, 2007, and response email from Noel Rosha with attachments, May 11, 2007. See Appendix A for copies.

16 Personal notes from Telephone Conference, Noel Rosha (Ceram) with Robert Blakley, Carl Weilert, and Steve Benson (EERC), April 23, 2008.

17 Electronic mail, Robert Blakley to Noel Rosha (Ceram) April 22, 2008, and response email from John Cochran, May 6, 2008. See Appendix A for copies.

18 Electronic mail, Robert Blakley to Scot Pritchard (Cormetech) April 18, 2007, and May 14, 2007 email reply. See Appendix A for copies.

19 Electronic mail, Robert Blakley to Flemming Hansen (Haldor Topsoe) April 18, 2007, and response email, May 10, 2007. See Appendix A for copies.

20 Personal notes from Telephone Conference, Flemming Hansen (Haldor Topsoe), with Robert Blakley, Carl Weilert, and Steve Benson (EERC), April 24, 2008.

21 Electronic mail, Robert Blakley to Flemming Hansen (Haldor Topsoe), April 28, 2008, and response email May 5, 2008. See Appendix A for copies.

22 Electronic mail, Robert Blakley to Flemming Hansen (Haldor Topsoe), May 5, 2008, and response email by Joakim Thøgersen (Haldor Topsoe) May 7, 2008. See Appendix A for copies.

23 Personal notes from Telephone Conference, Dr. Joakim Thøgersen (Haldor Topsoe) call to EERC with Steve Benson (EERC), May 2, 2008.

24 Personal notes from Telephone Conference, Wayne Jones (Haldor Topsoe), with Robert Blakley, April 22, 2008.

25 "*Ash Impacts On SCR Catalyst Performance*", Steven A. Benson, Ph.D., Energy & Environmental Research Center (EERC) of the University of North Dakota", October 2005.

26 Electronic mail, Robert Blakley to Anthony Favale (Hitachi), April 18, 2007, and response email, May 11, 2007. See Appendix A for copies.

27 Burns & McDonnell, EERC, and Hogan & Hartson, *"Appropriateness Of Conducting Pilot Testing Of Selective Catalytic Reduction (SCR) Technology At Milton R. Young Station Units 1 And 2 For Use In A NOx BACT Analysis, August 14, 2007".*

28 *EPA New Source Review Workshop Manual, Prevention of Significant Deterioration and Nonattainment Area Permitting, Draft October 1990* (The "NSR Manual").

29 Burns & McDonnell, "*BACT Analysis Study for Milton R. Young Station Unit 1 Minnkota Power Cooperative, Inc.*" and a separate "*BACT Analysis Study for Milton R. Young Station Unit 2 Square Butte Electric Cooperative*", October 2006, submitted to EPA Region 8 and EPA Office of Regulatory Enforcement, and included with the "*BART DETERMINATION STUDY for Milton R. Young Station Unit 1 and 2 Minnkota Power Cooperative, Inc. Final Report, October 2006*" submitted by Minnkota to North Dakota Department of Health.

APPENDIX A -

Initial Vendor Responses to 4/18/2007 SCR Vendor Query Information Request (and Attachments), May 2007, and Followup Vendor Responses to 4/18/2007 SCR Vendor Query Information Request (and Attachments), May 2008, arranged in alphabetical and chronological order by vendor name.

From: Blakley, Robert
Sent: Wednesday, April 18, 2007 3:58 PM
To: 'Charles.nordhausen@power.alstom.com'
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

Chuck,

On behalf of Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative (Minnkota), Burns & McDonnell (B&McD) is exploring the willingness of Selective Catalytic Reduction (SCR) vendors to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at Milton R. Young Station (MRYS). Minnkota's Unit 1 and Square Butte Electric Cooperative's Unit 2 each fire 100% North Dakota lignite using cyclone furnaces in subcritical boilers.

Burns & McDonnell requests Alstom to review the attached request document and respond within three weeks if possible. If Alstom's response is expected to extend beyond the timeframe requested, please advise with an estimated date when such a response could be provided.

<MRY SCR Vendor Query (4-18-07 final).doc>

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
Project Engineer
Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: charles.nordhausen@power.alstom.com [mailto:charles.nordhausen@power.alstom.com]
Sent: Wednesday, May 30, 2007 11:03 AM
To: Blakley, Robert
Cc: mike.phillips@power.alstom.com; john.buschmann@power.alstom.com; kthingelstad@minnkota.com; jgraves@minnkota.com
Subject: Re: Request for Lignite SCR Feasibility Commercial and Technical Information

Bob,

Please find attached the Alstom ECS response to the Burns and McDonnell RFI on behalf of Minnkota Power. If you have any further questions or would like to discuss this topic further, do not hesitate to contact me.

Best Regards,

Chuck

Chuck Nordhausen
Alstom GPS
Office: (913) 393-2585
Mobile: (651) 492-7420

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Power Turbo-Systems / Power Environment

Environmental Control Systems
North America

May 30, 2007

Mr. Robert Blakley
Burns and McDonnell
9400 Ward Parkway
Kansas City, MO 64114

Subject: Request For SCR Information
Milton Young Units 1&2

Dear Mr. Blakley:

As Burns and McDonnell and Minnkota Power are aware, ND Lignite does create many challenges for SCRs, but even with all of those challenges, it is possible to use ND Lignite if the system is designed properly and Minnkota Power elects to pay for the increased capital and O&M costs associated with this fuel. Alstom Power Environmental Control Systems (ECS) would like to offer Burns and McDonnell and Minnkota Power the following information in response to your request for SCR information on ND Lignite:

- Prior Applications of SCR to ND lignite fired boilers
- Alternative Tail End SCR
- Predicted SCR Performance
- Indicative Pricing and Delivery for Conventional SCR

Prior Applications of SCR to ND lignite fired boilers

Lignite coal burning units have not yet had any post combustion NOx controls installed on these units as environmental regulations have not yet required the installation of these controls. Investigative tests were performed on TXU Energy's Martin Lake Unit 3 to evaluate SCR catalyst performance on Texas-lignite-fired units. An in-situ mini SCR reactor was used for long-term tests on two types of catalyst to collect data on the effects of Texas lignite on SCR catalyst life and performance. After approximately 8000 hours of exposure to economizer outlet flue gas at typical SCR velocities of 15-20 ft./sec. (4.6-6.1 m/sec), both honeycomb and plate-type catalyst samples were shown, by field test, to have relative activities (K/K0) in the range of 0.70 to 0.75. Laboratory tests of catalyst activity performed by the catalyst vendors were consistent with these field test results. These results are expected

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to be representative of the first layer of a full-scale SCR reactor system. Erosion of the catalyst samples was not significant enough to affect catalyst performance. Test results further suggest that applying SCR catalyst technology (using even a high-dust design) to Texas-lignite-fired power generating units may be a practical approach for NOx control. (Electric Power Research Institute, December 2003, "Impacts of Texas Lignite Coal on SCR Catalyst Life and Performance: Field Data from TXU's Martin Lake Plant")

It should be noted that North Dakota lignite is higher in sodium than Texas lignite. Fuels high in sodium and potassium require special selection of catalyst, but can be treated by SCR. An example of a such an application would be wood and other biofuel fired boilers in Europe. While SCR catalyst life in ND lignite service is not expected to be as long as in bituminous coal service, it is expected that acceptable emissions control and maintenance requirements can be achieved. Based on experience with wood fired units, a hot side (600-750 deg F) ESP is effective in removing the fly ash compounds that result in catalyst poisoning.

Proper operation of the SCR generally requires that the system operate in a temperature range of 600 to 750 deg F. Per the information provided, the Milton R Young boiler flue gas temperature at the economizer outlet currently varies quite a bit outside this range. Based on this temperature information, we anticipate that modification or replacement of the economizer will be required to control the temperature within an acceptable range.

Alternative Tail End SCR

While likely more expensive, an alternative solution to the conventional SCR , is a Tail End SCR where the SCR is located just before the stack. For this application, the location of the SCR just before the stack can provide significant advantages. The economizer outlet temperature variations will have no effect on the SCR, and the fly ash constituents that can poison the catalyst will have been removed from the flue gas stream by the existing ESPs. This would mean that modification of the existing economizer and any existing ESP would not be required with the application of a Tail End SCR.

The key disadvantage of the Tail End SCR is that the flue gas stream will need to be reheated from the current stack temperature up to approximately 600 deg F. Typically the flue gas is reheated using natural gas, however high pressure steam has been used in some cases. Heat recovery can be utilized to reduce the amount of energy required, however, the heating requirement is typically in the range of tens of millions of Btu per hour.

Predicted SCR Performance

Designed properly, the SCR should be capable of up to 90% removal efficiencies with an associated ammonia slip below 2 ppm. The significant unknown is how often the catalyst itself would need to be replaced. There is minimal field data to demonstrate expected catalyst life, but lab results suggest an average up to 16,000 hours between replacements.

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Indicative Pricing, Sizing and Delivery

Because of the unusual design associated with this SCR and the potential additional scope items (heat exchangers or hot ESPs) required, it is expected that the cost will be significantly higher than for a conventional bituminous coal fired SCR. Without detailed anlaysis, the material and labor pricing below is our best estimate of the cost of a conventional SCR based on the increased sizing requirements.

Milton Young 1:	$50M
Milton Young 2:	$75M
Lead Time:	32 to 36 months

This estimated pricing does not include BOP costs, costs to modify the economizer, costs to modify existing precipitators, or costs to install gas to gas heat exchangers. Obviously, depending on the path forward and the resultant equipment required, the costs could be even more than stated above.

Alstom Power ECS hopes that this information can assist you in your SCR decision for Milton Young. In summary, it is possible to design and operate an SCR on this fuel if required, but doing so is not without challenges and can be very costly depending on which approach you may choose to pursue. Should you decide to pursue an SCR for these units, Alstom would be very interested in supporting you as we consider ourselves one of the industry leaders in this technology. Please contact Chuck Nordhausen, John Buschmann or me at your convenience with any questions or clarifications regarding this discussion.

Respectfully Submitted,

Michael G. Phillips
Business Applications Manager
Environmental Control Systems

CC: John Graves
Karen Thingelstad

From: Blakley, Robert
Sent: Monday, April 28, 2008 3:29 PM
To: 'john.buschmann@power.alstom.com'
Cc: 'charles.nordhausen@power.alstom.com'; 'mike.phillips@power.alstom.com'
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

John -

Thank you for discussing the issues of SCR feasibility involving North Dakota lignite-fired cyclone boilers.

Hopefully you've gotten a chance to revisit the April 18, 2007 query, and review results of pilot SCR testing performed at Coyote Station, on a boiler of the same size, cyclones and similar fuel as fired at Milton R. Young Station's Unit 2 boiler.

We would appreciate an email response to this followup, with discussion of the technical research and experience basis of Alstom's positions on catalyst fouling, poisoning, and blinding appropriate to high sodium, medium sulfur coal flyash and flue gas produced from these boilers, both in hot-side/high-dust and low-dust/tail end SCR applications.

We are interested in learning more about the basis of lab results mentioned in discussion of the 16,000 hours as a suggested number of operating hours between catalyst replacements. Particularly, if Alstom were asked to provide a catalyst service life guarantee and replacement warranty, whether this or any other operating time that Alstom would propose is based on the special nature of this fuel and ash composition method of firing (in a cyclone) and the location relative to gas cleaning equipment. As mentioned during our telephone conference, the April 2007 SCR vendor query contained evidence of fine sodium particles downstream of MRY Station Unit 2's cold-side ESP and wet FGD scrubber.

We are also interested in knowing more about Alstom's willingness to offer SCR performance guarantees, and what that would include from a commercial standpoint along with a catalyst warranty. Of particular interest is whether Alstom's guarantee would satisfy a "make good" requirement, require full-scale field testing of each boiler prior to catalyst selection and design, testing catalyst in a slipstream arrangement or other exposure demonstrations, and if there are any other qualifiers beyond the assumption that the high flue gas temperatures in a conventional hot-side, high-dust SCR were limited by a solution to these temperature conditions yet to be developed.

It would be beneficial to reference Alstom's previous May 30, 2007 response when sending a supplemental response addressing this subject and issues raised in today's discussion.

We realize that this is a concentrated effort that does not allow much time to review and provide such responses.

We ask that Alstom provide their email response by Monday, 5/5 12 pm (noon), so that we can review this and forward to Minnkota.

Again, thank you for your attention to this matter.

Bob Blakley
Burns & McDonnell
(816) 822-3842

From: mike.phillips@power.alstom.com
[mailto:mike.phillips@power.alstom.com]
Sent: Tuesday, May 06, 2008 8:55 AM
To: Blakley, Robert
Cc: charles.nordhausen@power.alstom.com;
john.buschmann@power.alstom.com
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Sorry for the delay!

(See attached file: Response to B&M for Minnkota SCR Inquiry 050608.doc.zip)

Regards,
Mike

Michael G. Phillips
513-543-0055 mobile
865-560-1389 office
1409 Centerpoint Blvd.
Knoxville, TN. 37932

ALSTOM

Power Turbo-Systems / Power Environment
Environmental Control Systems
North America

May 5, 2008

Mr. Robert Blakely
Burns and McDonnell
9400 Ward Parkway
Kansas City, MO 64114

Subject: Minnkota Power Cooperative
Milton R Young SCR Inquiry

Dear Mr. Blakely:

Alstom Power Environmental Control Systems (ECS) has reviewed the information available to us regarding SCR installations on ND Lignite units and feel that our original response to Minnkota dated May 27, 2007 is still valid. The highlights of that letter are clarified / summarized below.

- There are no known existing applications of SCR to ND lignite fired boilers, therefore there is some risk on any first a a kind application
- Alstom believes that hot side SCRs can be utilized in this application if a hot ESP is used upstream for ash collection before the SCR, but would as a result be very expensive from both a capital and O&M standpoint compared to non ND lignite SCRs
- In order to provide catalyst life guarantees, it is anticipated that catalyst manufacturers would require a pilot test of at least one year
- Tail end SCRs remain an alternative, but are also very expensive from a O&M standpoint

While SCR catalyst life in ND lignite service is not expected to be as long as in bituminous coal service, it is expected that acceptable emissions control and maintenance requirements can be achieved. Based on experience with wood fired units, a hot side (600-750 deg F) ESP is effective in removing the fly ash compounds that result in catalyst poisoning.

Proper operation of the SCR generally requires that the system operate in a temperature range of 600 to 750 deg F. Per the information provided, the Milton R Young boiler flue gas temperature at the economizer outlet currently varies quite a bit outside this range. Based on this temperature information, we anticipate that modification or replacement of the economizer will be required to control the temperature within an acceptable range.

Application of a traditional SCR to Lignite fired units will require some R&D, custom engineering, and likely a pilot testing program. This will be time consuming and expensive but will reduce the risks involved in a new application such as this one.

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While likely more expensive, an alternative solution to the conventional SCR , is a Tail End SCR where the SCR is located just before the stack. For this application, the location of the SCR just before the stack can provide significant advantages. The economizer outlet temperature variations will have no effect on the SCR, and the fly ash constituents that can poison the catalyst will have been removed from the flue gas stream by the existing ESPs. This would mean that modification of the existing economizer and any existing ESP would not be required with the application of a Tail End SCR.

We hope this helps assist you with Minnkota on its future NOx requirements Please contact Chuck Nordhausen, John Buschmann or me at your convenience with any questions or clarifications. We look forward to having the opportunity to meet with you to discuss our proposal in detail.

Respectfully Submitted,

Michael G. Phillips
Business Sales Manager
Environmental Control Systems

Cc: Chuck Nordhausen – Alstom GPS
John Buschmann – Alstom ECS

From: Khalaf Cindy R [mailto:Cindy.Khalaf@argillon.com]
Sent: Thursday, April 19, 2007 4:50 AM
To: Blakley, Robert
Subject: Re: Request for Lignite SCR Feasibility Commercial and Technical Information

Robert,
We'll take a look and let you know if we need longer. Bruce Gobbel will be responding. Have you taken Bob Johnson's pllace?
Regards,
Cindy

Sent from my BlackBerry Wireless Handheld

From: Blakley, Robert
Sent: Wednesday, April 18, 2007 3:48 PM
To: 'cindy.khalaf@argillon.com'
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

Cindy,

On behalf of Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative (Minnkota), Burns & McDonnell (B&McD) is exploring the willingness of Selective Catalytic Reduction (SCR) vendors to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at Milton R. Young Station (MRYS). Minnkota's Unit 1 and Square Butte Electric Cooperative's Unit 2 each fire 100% North Dakota lignite using cyclone furnaces in subcritical boilers.

Burns & McDonnell requests Argillon to review the attached request document and respond within three weeks if possible. If Argillon's response is expected to extend beyond the timeframe requested, please advise with an estimated date when such a response could be provided.

<MRY SCR Vendor Query (4-18-07 final).doc>

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
Project Engineer
Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: Blakley, Robert [mailto:rblakley@burnsmcd.com]
Sent: Wednesday, April 18, 2007 3:59 PM
To: Moorman, Steve A
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

Steve,

On behalf of Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative (Minnkota), Burns & McDonnell (B&McD) is exploring the willingness of Selective Catalytic Reduction (SCR) vendors to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at Milton R. Young Station (MRYS). Minnkota's Unit 1 and Square Butte Electric Cooperative's Unit 2 each fire 100% North Dakota lignite using cyclone furnaces in subcritical boilers.

Burns & McDonnell requests Babcock & Wilcox to review the attached request document and respond within three weeks if possible. If B&W's response is expected to extend beyond the timeframe requested, please advise with an estimated date when such a response could be provided.

<MRY SCR Vendor Query (4-18-07 final).doc>

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
Project Engineer
Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: Moorman, Steve A [mailto:samoorman@babcock.com]
Sent: Wednesday, May 09, 2007 4:44 PM
To: Blakley, Robert
Cc: Telesz, Robert W; Hansen, Elizabeth A
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Robert,

The Babcock & Wilcox Company has reviewed your request of April 18, 2007 regarding information related to the application of SCR technology on steam generating units that fire North Dakota lignite.

As you indicate in your Information Request, there is no full scale operational experience with SCR systems that have been retrofit onto an ND lignite-fired boiler. In fact, we are aware of no SCR retrofit that to date has been done on any boiler here in the US where lignite of any type has been fired. Therefore, neither we nor any other SCR system supplier can "provide detailed information regarding the post-combustion controlled emissions rates that full-scale, full-time SCR systems in lignite-fired coal-burning boiler operations have consistently achieved over a period of time."

B&W agrees with Burns & McDonnell that there are significant challenges associated with both boiler operation (high economizer exit gas temperature) and lignite firing (flue gas constituents) at Milton R. Young Station (MRYS). We have had cursory conversations with catalyst suppliers in an attempt to better understand and quantify these challenges. However we have not been able to fully explore these issues and at this time have no knowledge of the full extent of the catalyst suppliers concerns or the lengths to which they may need to go to address them especially if catalyst guarantees must be offered. In addition, with the limited number of units firing North Dakota lignites, it would be difficult for a supplier like B&W to justify investing significant dollars in R&D efforts to fully investigate and understand both the technical and commercial risks that would be involved when installing SCRs on ND lignite fired boilers.

During our delivery of over 26,000 MW of SCR systems and our evaluation of several times that many customer inquiries, B&W has identified creative solutions to address a host of boiler-SCR system integration challenges. Some were implemented while others were necessarily abandoned as economically unfeasible. B&W would welcome the opportunity to work with Burns & McDonnell and the Minnkota Power Cooperative, Inc. to further investigate opportunities to successfully meet the NOx emission challenges at MRYS should Minnkota find it necessary to do so.

Steve Moorman

Steve Moorman --- District Sales Manager, Babcock & Wilcox

2096 Edgcumbe Road Saint Paul, MN 55116

Office 651-690-3795, Home 651-690-1558, Cell 612-670-8261

From: Blakley, Robert
Sent: Wednesday, April 18, 2007 4:02 PM
To: 'rabrams@babcockpower.com'
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

Rich,

On behalf of Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative (Minnkota), Burns & McDonnell (B&McD) is exploring the willingness of Selective Catalytic Reduction (SCR) vendors to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at Milton R. Young Station (MRYS). Minnkota's Unit 1 and Square Butte Electric Cooperative's Unit 2 each fire 100% North Dakota lignite using cyclone furnaces in subcritical boilers.

Burns & McDonnell requests Babcock Power to review the attached request document and respond within three weeks if possible. If Babcock Power's response is expected to extend beyond the timeframe requested, please advise with an estimated date when such a response could be provided.

<MRY SCR Vendor Query (4-18-07 final).doc>

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
Project Engineer
Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: rabrams@babcockpower.com [mailto:rabrams@babcockpower.com]
Sent: Friday, May 11, 2007 1:37 PM
To: Blakley, Robert
Cc: cerickson@babcockpower.com; MGialanella@babcockpower.com; Perrie Schafer; dgustafson@babcockpower.com
Subject: Re: Request for Lignite SCR Feasibility Commercial and Technical Information

Dear Mr. Blakely:

Babcock Power Environmental (BPE) has reviewed the information provided to us on Milton Young Units 1 & 2 lignite fired boiler and the request for information on the applicability of SCR technology these boilers and their fuel. As you are aware, there have been a few tests performed to ascertain the possibility of using a high dust SCR on lignite and the potential for fouling/poisoning of the catalyst has been in question.

BPE and its licensor have supplied >60,000 MW of SCR systems around the world, including in applications with lignite in Europe and active lignite projects in the states. We have examined the various lignite fuels from around the world and, while there are differences, we expect an SCR system could be successfully utilized on a boiler fired with Northern lignite fuel however, uncertainty exists because an SCR has yet to be tested/provided on a meaningful scale to a Northern lignite application.

Furthermore, during our review of the information provided, we have identified the MY1 and MY2 boilers as a very difficult one on which a high dust SCR would be applied because of the unique configuration of the boiler and the wide temperature swings that are encountered.

BPE is very interested in working with Burns & McDonnell and Minnkota Power to provide the optimum solution to this problem. Several possible solutions exist with varying certainties of outcome. The SCR technology location may potentially mitigate the issues with the possible poisoning of the catalyst by constituents in the gas from the combustion of Northern lignite.

We recommend an engineering study be conducted to evaluate three key issues:

Initial estimates of the actual deactivation of SCR catalyst in the high dust location by the use of coupons positioned in the hot gas stream downstream of the economizer.

Initial estimates of the actual deactivation of SCR catalyst in other locations by the use of coupons positioned in the gas stream downstream of the airheater.

Possibility of a retrofit of an SCR into the MY1 and MY2 boiler considering the wide range of temperature for the flue gas and possible boiler modifications required.

BPE would lead this effort with collaboration from Burns & McDonnell and Minnkota Power. .

BPE is planning to be in the Bismarck area during the week of June 18 and offer to visit the plant and to meet to discuss our thoughts on the program, its cost, and the sharing of those costs. Furthermore, we would like to discuss issue #3 in greater detail to better understand options in the boiler area. Please let me know the availability of Minnkota and B&Mc personnel to meet and discuss this subject. We look forward to hearing from you.

Rich Abrams
Director of Business Development
Babcock Power Environmental Inc.
Worcester, Massachusetts
Phone: 508.854.1140

From: Blakley, Robert
Sent: Monday, April 28, 2008 3:41 PM
To: cerickson@babcockpower.com
Cc: MGialanella@babcockpower.com; rabrams@babcockpower.com; Tyler Schafer; 'jlangone@babcockpower.com'; Perrie Schafer
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Clay -

Thank you for discussing the issues of SCR feasibility involving North Dakota lignite-fired cyclone boilers.

Hopefully you've gotten a chance to revisit the April 18, 2007 query, and review results of pilot SCR testing performed at Coyote Station, on a boiler of the same size, cyclones and similar fuel as fired at Milton R. Young Station's Unit 2 boiler.

We would appreciate an email response to this followup, with discussion of the technical research and experience basis of Babcock Power's positions on catalyst fouling, poisoning, and blinding appropriate to high sodium, medium sulfur coal flyash and flue gas produced from these boilers, both in hot-side/high-dust and low-dust/tail end SCR applications.

We are interested in learning more about the "fatal flaw" SCR catalyst coupon testing approach mentioned in today's discussion, and additional pilot-scale SCR catalyst testing in various locations relative to gas cleaning equipment.

We are also interested in knowing more about Babcock Power's willingness to offer SCR performance guarantees, and what that would include from a commercial standpoint along with a catalyst warranty. Of particular interest is whether Babcock Power's guarantee would satisfy a "make good" requirement, require full-scale field testing of each boiler prior to catalyst selection and design, testing catalyst in a slipstream arrangement or other exposure demonstrations, and if there are any other qualifiers beyond the assumption that the high flue gas temperatures in a conventional hot-side, high-dust SCR were limited by a solution to these temperature conditions yet to be developed. Particularly, if Babcock Power were asked to provide a catalyst service life guarantee and replacement warranty, whether a minimum operating time that Babcock Power would propose is based on the special nature of this fuel and ash composition method of firing (in a cyclone) and the location relative to gas cleaning equipment. As mentioned during our telephone conference, the April 2007 SCR vendor query contained evidence of fine sodium particles downstream of MRY Station Unit 2's cold-side ESP and wet FGD scrubber.

It would be beneficial to reference Babcock Power's previous May 11, 2007 response when sending a supplemental response addressing this subject and issues raised in today's discussion.

We realize that this is a concentrated effort that does not allow much time to review and provide such responses.

We ask that Babcock Power provide their email response by Monday, 5/5 12 pm (noon), so that we can review this and forward to Minnkota.

Again, thank you for your attention to this matter.

Bob Blakley
Burns & McDonnell

From: cerickson@babcockpower.com [mailto:cerickson@babcockpower.com]
Sent: Tuesday, May 06, 2008 10:58 AM
To: Blakley, Robert
Cc: MGialanella@babcockpower.com; jlangone@babcockpower.com
Subject: Lignite SCR Response

Robert,

Per our phone conversion concerning the application of SCR technology to Northern Lignite fired boilers, BPEI has not nor knows of any further work on this topic since the response provided below on May 11th 2007. As discussed BPEI believes the issues related to the application of SCR technology for northern lignite fired units to be addressable in design.
The EERC reports have indicated significant issues however BPEI feels further tests investigating different locations and using tests alternate methods must be performed to make a final determination. BPEI, as the worldwide leader in SCR technology, continues to offer its services for to the industry to resolve the application of SCR technology to northern lignite fired units.

If you have further questions please contact me or Joe Langone.

Clay Erickson

May 11th 2007 Response below

Babcock Power Environmental (BPE) has reviewed the information provided to us on Milton Young Units 1 & 2 lignite fired boiler and the request for information on the applicability of SCR technology these boilers and their fuel. As you are aware, there have been a few tests performed to ascertain the possibility of using a high dust SCR on lignite and the potential for fouling/poisoning of the catalyst has been in question.

BPE and its licensor have supplied >60,000 MW of SCR systems around the world, including in applications with lignite in Europe and active lignite projects in the states. We have examined the various lignite fuels from around the world and, while there are differences, we expect an SCR system could be successfully utilized on a boiler fired with Northern lignite fuel however, uncertainty exists because an SCR has yet to be tested/provided on a meaningful scale to a Northern lignite application.

Furthermore, during our review of the information provided, we have identified the MY1 and MY2 boilers as a very difficult one on which a high dust SCR would be applied because of the unique configuration of the boiler and the wide temperature swings that are encountered.

BPE is very interested in working with Burns & McDonnell and Minnkota Power to provide the optimum solution to this problem. Several possible solutions exist with varying certainties of outcome. The SCR technology location may potentially mitigate the issues with the possible poisoning of the catalyst by constituents in the gas from the combustion of Northern lignite.

We recommend an engineering study be conducted to evaluate three key issues:

Initial estimates of the actual deactivation of SCR catalyst in the high dust location by the use of coupons positioned in the hot gas stream downstream of the economizer.

Initial estimates of the actual deactivation of SCR catalyst in other locations by the use of coupons positioned in the gas stream downstream of the airheater.

Possibility of a retrofit of an SCR into the MY1 and MY2 boiler considering the wide range of temperature for the flue gas and possible boiler modifications required.

BPE would lead this effort with collaboration from Burns & McDonnell and Minnkota Power. .

(Embedded image moved to file: pic24350.gif)

BabcockPower

Clayton Erickson, PhD
Director, Process Engineering
Babcock Power Inc.
5 Neponset Street
Worcester, MA 01606

T: 508-854-4039 F: 508-854-1177
M: 508-245-2383

cerickson@babcockpower.com
http://www.babcockpower.com

From: Blakley, Robert
Sent: Wednesday, April 18, 2007 3:50 PM
To: 'john.cochran@ceram-usa.com'
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

John,

On behalf of Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative (Minnkota), Burns & McDonnell (B&McD) is exploring the willingness of Selective Catalytic Reduction (SCR) vendors to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at Milton R. Young Station (MRYS). Minnkota's Unit 1 and Square Butte Electric Cooperative's Unit 2 each fire 100% North Dakota lignite using cyclone furnaces in subcritical boilers.

Burns & McDonnell requests Ceram to review the attached request document and respond within three weeks if possible. If Ceram's response is expected to extend beyond the timeframe requested, please advise with an estimated date when such a response could be provided.

<MRY SCR Vendor Query (4-18-07 final).doc>

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
Project Engineer
Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: Noel Rosha [mailto:Noel.Rosha@CERAM-USA.COM]
Sent: Friday, May 11, 2007 4:44 PM
To: Blakley, Robert
Cc: John Cochran
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

Mr. Blakley,

CERAM has reviewed the information provided by Burns & McDonnell regarding the technical feasibility of SCR on the Milton R. Young Station Units 1 and 2 firing North Dakota Lignite fuel. Based on the information provided we have developed preliminary catalyst designs for each Unit, as outlined in the attached files. Unit 1 and Unit 2 were both designed with 85% NOx reduction (0.08 lb/MBtu outlet) with an SO_2 to SO_3 conversion rate of 1.0% and ammonia slip of 2.0 ppm for a guarantee life of 16,000 hours. We have also included for your information our high temperature reference list.

CERAM currently does not have a catalyst installation with North Dakota Lignite fuel. CERAM does have a very wide fuels experience base for coals, including one brown coal reference in Europe. We also have a large experience base with refineries and incinerators and are familiar with the affects of a wide range of fuel and flue gas constituents.

North Dakota Lignite fuel and ash characteristics present certain challenges related to SCR operation and reliability. Additionally, the high flue gas temperatures needed for purposes of drying the fuel can be a challenge for SCR catalyst design. Please note the following technical clarifications that CERAM feels are pertinent for this application:

- The presence of pyrosulfates (sodium, iron and sulfur) have the potential to increase the SO_2 to SO_3 conversion rate. Based on this, CERAM could only guarantee the initial SO_2 to SO_3 conversion rate and not the end of life conversion rate.
- CERAM has utilized a 7.4 mm pitch catalyst to minimize risk of catalyst pluggage. High concentrations of calcium and sulfates in the fuel increase the potential for catalyst pluggage.
- Due to the high sodium and iron concentrations, CERAM would recommend a full SCR bypass system be installed. During lay-up periods the catalyst would need to remain warm and dry, for instance with an air drying or dehumidification system.
- CERAM would require the maximum continuous operating temperature of the SCR be designed for 850° F. Short periods of operation up to 900° F could be allowed. Boiler outlet temperatures greater than these would require flue gas tempering prior to reaching the SCR reactor.

Please let us know if you have further questions or would like additional information.

Best regards,

Noel Rosha
Applications Engineer

CERAM Environmental, Inc.
7304 W. 130th Street, Suite 140
Overland Park, KS 66213

Phone: (913) 239-9896
Fax: (913) 239-9821

CERAM CATALYSTS + HONEYCOMBS	**PROJECT**	**Milton R. Young Unit 1**
	DATE	4/23/2007
	PREPARED BY	Noel Rosha
	REVISION	0
	PROPOSAL NO.	NR042307-1

Design Basis:

	Case	Limiting case
		Design Load
	Load	Design Load
	Fuel	North Dakota Lignite
Gas flow	acfm,w	2483737
Gas temperature	°F	850
H_2O	Vol%	18.87
O_2-actual	Vol%,w	2.87
O_2-reference	Vol%,d	3.00
Inlet NOx	lb/MMBtu	0.53
SO_2	lb/hr	8970.0
SO_3	lb/hr	135.0
Particulate	lb/hr	20809.0

Catalyst Design:

Orientation				Vertical
Catalyst Volume per reactor	m^3			**625.7**
Number of SCR reactors	[-]			1
Number of units	[-]			1
Catalyst Volume, total	m^3			**625.7**
Cells of catalyst n x n	[-]			20
Specific area of catalyst Ap	m^2/m^3			469
Pitch of catalyst	mm			7.4
Catalyst length	mm			1071
Catalyst elements per one module	n x n	6	x	12
Number of layers per reactor				3
Module arrangement per layer	n x n	12	x	10
Module dimensions:				
length x width	mm x mm	958	x	1901
	ft x ft	3.14	x	6.24
height	mm			1411
	ft			4.63
Reactor dimensions:				
length x width	mm x mm	11816	x	19830
	ft x ft	38.77	x	65.06
Weight per module incl. catalyst	kg			1115
	lb			2457
Module frame material				H II

CERAM CATALYSTS + HONEYCOMBS		
	PROJECT	**Milton R. Young Unit 1**
	DATE	4/23/2007
	PREPARED BY	Noel Rosha
	REVISION	0
	FILE	NR042307-1

Catalyst Performance:

	Case	Limiting case
		Design Load
	Load	Design Load
	Fuel	North Dakota Lignite
NOx outlet	ppmvd,ref.O_2	43.2
	lb/MMBtu	0.08
NOx reduction rate	%	85
NH_3 slip	ppmvd,ref.O2	2.0
NH3 100% consumption	kg/h	249.5
per reactor	lb/h	550.0
Catalyst pressure drop, clean	mbar	6.0
	inwg	2.4
	mm WC	61.1
Catalyst pressure drop, dirty	mbar	6.6
	inwg	2.7
	mm WC	67.4
SO_2/SO_3 conversion rate	%	1.00
Catalyst life	hr / years	16000 / 2

Technical Requirements:

Minimum NH_3 injection temperature	°C	317
	°F	602
Molar ratio distribution	% absolute	10
Velocity distribution	% absolute	15
Temperature distribution	°C absolute	10
Soot blower or sonic horns	yes / no	y

CERAM CATALYSTS + HONEYCOMBS		
	PROJECT	Milton R. Young Unit 2
	DATE	4/23/2007
	PREPARED BY	Noel Rosha
	REVISION	0
	PROPOSAL NO.	NR042307-1

Design Basis:

	Case	Limiting case
		Design Load
	Load	Design Load
	Fuel	North Dakota Lignite
Gas flow	acfm,w	4371000
Gas temperature	°F	818
H_2O	Vol%	17.08
O_2-actual	Vol%,w	4.77
O_2-reference	Vol%,d	3.00
Inlet NOx	lb/MMBtu	0.52
SO_2	lb/hr	15474.0
SO_3	lb/hr	236.0
Particulate	lb/hr	34584.0

Catalyst Design:

Orientation				Vertical
Catalyst Volume per reactor	m³			**947.1**
Number of SCR reactors	[-]			1
Number of units	[-]			1
Catalyst Volume, total	m³			**947.1**
Cells of catalyst n x n	[-]			20
Specific area of catalyst Ap	m²/m³			469
Pitch of catalyst	mm			7.4
Catalyst length	mm			1298
Catalyst elements per one module	n x n	6	x	12
Number of layers per reactor				2
Module arrangement per layer	n x n	15	x	15
Module dimensions:				
length x width	mm x mm	958	x	1901
	ft x ft	3.14	x	6.24
height	mm			1638
	ft			5.37
Reactor dimensions:				
length x width	mm x mm	14750	x	29735
	ft x ft	48.39	x	97.56
Weight per module incl. catalyst	kg			1310
	lb			2889
Module frame material				H II

CATALYSTS + HONEYCOMBS

PROJECT	**Milton R. Young Unit 2**
DATE	4/23/2007
PREPARED BY	Noel Rosha
REVISION	0
FILE	NR042307-1

Catalyst Performance:

	Case	Limiting case
		Design Load
	Load	Design Load
	Fuel	North Dakota Lignite
NOx outlet	ppmvd,ref.O_2	44.7
	lb/MMBtu	0.08
NOx reduction rate	%	85
NH_3 slip	ppmvd,ref.O2	2.0
NH3 100% consumption per reactor	kg/h	370.5
	lb/h	816.7
Catalyst pressure drop, clean	mbar	4.3
	inwg	1.8
	mm WC	44.2
Catalyst pressure drop, dirty	mbar	4.8
	inwg	1.9
	mm WC	48.7
SO_2/SO_3 conversion rate	%	1.00
Catalyst life	hr / years	16000 / 2

Technical Requirements:

Minimum NH_3 injection temperature	°C	316
	°F	602
Molar ratio distribution	% absolute	10
Velocity distribution	% absolute	15
Temperature distribution	°C absolute	10
Soot blower or sonic horns	yes / no	y

CERAM
CATALYSTS + HONEYCOMBS

Reference List for High Temperature SCR Applications ($\geq$ 400°C / 752°F)

as of August 2006

Project	Client	End user / Engineering company	Plant location	Application	SCR-temperature	Shipped quantity	Delivery date
FHKW Mellach	SGP	STEWEAG	AUT	Bituminous coal, High dust	400°C 752°F	287 m^3	1986
BHKW Donaustadt Block 2	SGP	Wiener Stadtwerke	AUT	Oil / Gas	420°C 788°F	80 m^3	1987
BHKW Donaustadt Block 1	SGP	Wiener Stadtwerke	AUT	Oil / Gas	420°C 788°F	80 m^3	1988
FHKW Mellach 4. Lage	SGP	STEWEAG	AUT	Bituminous coal, High dust	400°C 752°F	94 m^3	1988
Weiher 3	Steinmüller	SaarEnergie	DEU	Coal, High dust	400 - 420°C 752 - 788°F	617 m^3	1990
VA-Stahl 85 MW Block 6	AEE	VÖEST Alpine Stahl	AUT	Blast furnance-, Coking plant- and Natural gas	420°C 788°F	41 m^3	1994
FHKW Mellach	AEE	STEWEAG	AUT	Bituminous coal, High dust, Additional delivery	400°C 752°F	95 m^3	1995
Smurfit Newsprint, Pomona	WAHLCO	Energy Products of Idaho	USA	Natural gas	440°C 824°F	26 m^3	2000
Hot Strip Mill Oven 22	Seiler	Hoogovens Staal BV	NLD	Steel production, Low dust, High temp.	550°C 1022°F	37 m^3	2000
Tripan	Tripan Leichtbauteile		AUT	Diesel engine	550°C 1022°F	1 m^3	2000
KW Weiher 3	BASF	Saarenergie	DEU	Coal, High dust, Additional delivery	400 - 420°C 752 - 788°F	369 m^3	2001
Hot Strip Mill Oven 21	Seiler	Hoogovens Staal BV	NLD	Steel production, Low dust, High temp.	550°C 1022°F	37 m^3	2002
PSEG Tracy	HRC	GWF Energy	USA	Natural gas, Simple cycle, High temp.	466 - 549°C 870 - 1020°F	44 m^3	2002
Michigan City Unit 12	Black & Veatch	NIPSCO	USA	Coal, High dust	427°C 800°F	583m^3	2002
KW Weiher 3	BASF	Saarenergie	DEU	Coal, High dust, Additional delivery	400 - 420°C 752 - 788°F	369 m^3	2002
Hot Strip Mill Oven 22	Seiler	Hoogovens Staal BV	NLD	Steel production, Low dust, High temp., Additional del.	550°C 1022°F	39 m^3	2002
Dallman Station Unit 33	Black & Veatch	City of Springfield	USA	Bituminous Coal, High dust	410°C 770°F	218 m^3	2002/3
Tracy	GWF Energy		USA	Nat. gas, GT Simple cycle, High temp., Additional del.	466 - 549°C 870 - 1020°F	44 m^3	2004

CERAM
CATALYSTS + HONEYCOMBS

Reference List for High Temperature SCR Applications ($\geq$ 400°C / 752°F)

as of August 2006

Project	Client	End user / Engineering company	Plant location	Application	SCR-temperature	Shipped quantity	Delivery date
Grenelle	HRC	CPCU	FRA	Heavy oil, High dust	420°C 788°F	35 m^3	2005
FHKW Mellach, Repl. 4th layer	VERBUND	VERBUND	AUT	Coal, High dust, Additional delivery	400°C 752°F	94 m^3	2005
Gas engines	BASF	Steuler	FRA	Gas engines, High temp.	approx. 500°C approx. 932°F	4 m^3	2005
Hot Strip Mill - Oven 23	Seiler	Corus Strip Products	NLD	Steel production, Low dust, Additional delivery	420°C 788°F	12 m^3	2006
Thomas Hill Unit 3	Associated Electric Coop.	Associated Electric Coop.	USA	Coal, High dust	404 - 427°C 760 - 800°F	802 m^3	2007
Hot Strip Mill - Oven 21	Seiler	Corus Strip Products	NLD	Steel mill Additional delivery	550°C 1022°F	21 m^3	2006
TOTAL AMOUNT						**3,425 m^3**	

From: Blakley, Robert
Sent: Monday, April 28, 2008 3:50 PM
To: 'Noel Rosha'
Cc: 'John Cochran'
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Noel -

We also would like Ceram to comment on this question: if Ceram were asked to provide a catalyst service life guarantee and replacement warranty, whether a minimum operating time that Ceram would propose would be based on the special nature of this fuel and ash composition method of firing (in a cyclone) and the location relative to gas cleaning equipment. As mentioned during our telephone conference, the April 2007 SCR vendor query contained evidence of fine sodium particles downstream of MRY Station Unit 2's cold-side ESP and wet FGD scrubber.

It would be good to note in the response to the above question whether Ceram would require additional SCR catalyst coupons or slip-stream pilot testing with laboratory analysis in order to be confident in their proposed catalyst selection, design, and performance and service life guarantees.

It would be beneficial to reference Ceram's previous May 11, 2007 response when sending a supplemental response addressing this subject and issues raised in our 4/23/08 discussion.

Bob Blakley
Burns & McDonnell
(816) 822-3842

From: Blakley, Robert
Sent: Monday, April 28, 2008 8:47 AM
To: 'Noel Rosha'
Cc: 'John Cochran'
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Noel & John -

Thank you for discussing the issues of SCR feasibility involving North Dakota lignite-fired cyclone boilers.

Hopefully you've gotten a chance to obtain Dr. Benson's paper on the pilot SCR testing performed at Coyote Station, on a boiler of the same size, cyclones and similar fuel as fired at Milton R. Young Station's Unit 2 boiler.

We would appreciate an email response to this followup, with discussion of the technical research and experience basis of Ceram's positions on catalyst fouling, poisoning, and blinding appropriate to high sodium, medium sulfur coal flyash and flue gas produced from these boilers.

We are also interested in knowing more about Ceram's willingness to offer performance guarantees, and what that would include from a commercial standpoint along with a catalyst warranty. Of particular interest is whether Ceram's guarantee would satisfy a "make good" requirement, require full-scale field testing of each boiler prior to catalyst selection and design, testing catalyst in a slipstream arrangement or other exposure demonstrations, and if there are any other qualifiers beyond the assumption that the high flue gas temperatures in a conventional hot-side, high-dust SCR were limited by a solution developed by others.

We realize that this is a concentrated effort that does not allow much time to review and provide such responses.

We ask that Ceram provide their email response by Monday, 5/5 12 pm (noon), so that we can review this and forward to Minnkota.

Again, thank you for your attention to this matter.

Bob Blakley
Burns & McDonnell
(816) 822-3842

From: John Cochran [mailto:John.Cochran@CERAM-USA.COM]
Sent: Tuesday, May 06, 2008 3:12 PM
To: Blakley, Robert
Cc: Noel Rosha; Greg Holscher; kurt.orehovsky@frauenthal.net
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Bob,

My apologies for not being able to meet your schedule for return of a response regarding your emails dated April 28, 2008.

We have reviewed the information provided including Dr. Benson's paper. We believe that the information and test work presented indicate that it is certainly premature to assume that there is a fatal flaw for the use of high dust SCR behind cyclones burning North Dakota lignite. The concerns presented are similar in argument to those that were used 10 years ago against the application of PRB for high dust applications. The results of the cited test reactor work for Baldwin and Columbia would even seemingly indicate that the use of high dust SCR on PRB applications would be similarly difficult to an installation on a lignite application. Meanwhile, dating from 1999 starting with the New Madrid project (a 2 by 660 MW cyclone base project burning 100% PRB where I was the responsible process engineer for Black & Veatch) there has been in excess of 25,000 MW of SCR installed on PRB fueled cyclone, wall, and tangential fired units with good success. Operating results for PRB units nonetheless indicate great success. The backpass fouling cited in the vendor query document is very similar to that found at the New Madrid project where backend temperatures rise from 720 F to 800 F every 6 months dependent on cleanliness. Meanwhile the cleanliness of the catalyst has been maintained to very low levels after 8 to 9 years of SCR operation.

Certainly a number of circumstances are present that necessitate a pragmatic approach to the application of catalyst for a lignite application. CERAM has more than 20 years of experience with dealing with all variety of fuels. Of particular concern with low rank fuels such as lignite and sub-bituminous coal is proper geometric and chemical design to address the unique characteristics of the ash and flue gas. As was well illustrated by the testing, the first critical parameter to consider is the geometric design of the catalyst. CERAM has experience with the slipstream test reactor used for testing at Baldwin and can confirm that this reactor is susceptible to ash accumulation due to wall effects. Additionally, the 6 mm pitch Haldor Topsoe catalyst used for the Coyote Station testing was an inadequate choice considering the ash loading and ash characteristics. Considering this choice of catalyst pitch and use of this slipstream reactor the results cannot be assumed to be representative of a full scale application. Based on the ash loading and chemistry for Milton R. Young Units 1 and 2 we would consider that at least a 7.4 mm pitch catalyst be utilized. This is the catalyst pitch we proposed in our May 11, 2007 budgetary sizing. A more conservative approach would be to use either an 8.2 or 9.2 mm catalyst. This could have alleviated the noted test element ash pluggage issues.

Sodium is a catalyst poison. Concerns reported by Dr. Benson regarding high sodium contents and fine fume are duly noted, but inadequate evidence is presented that this could be a fatal flaw to application of SCR considering the flawed pitch and resultant pluggage of the catalyst used during Coyote Station testing. Sodium is not a poison to catalyst at SCR operating temperatures. Significant deactivation can occur if condensed moisture transports sodium residing at the surface into the catalyst pore structure during outage or layup. CERAM has experience with high sodium applications to substantiate this effect. Important to avoid deactivation from sodium is the need to protect the catalyst from going through a condensation event.

With consideration of these factors we would agree that there is good cause for further testing on a lignite fired unit to further mitigate risks and optimize design. For this testing we would propose a program utilizing our CoPilot reactor (description attached) whereas wall effects can be minimized and representative ash loading can be better assured. The CoPilot reactor would be installed directly in the flue gas stream at the economizer outlet. The CoPilot reactor has been used in a number of difficult fuel circumstances to obtain accurate results supporting full scale design. If this testing is of interest to you we could prepare a test program proposal for your review.

CERAM can certainly confirm that there are certainly challenges present regarding the application of SCR to the Milton R Young Station. The following lists design requirements necessary to assure successful application of catalyst for Units 1 or 2.

- For coal, lignite, or sub-bituminous fired applications CERAM catalyst can be used to a maximum steady-state single point temperature of 900 F. Beyond this temperature severe permanent degradation of the catalyst will occur due to sintering. System configuration and design must ensure temperatures are maintained below 900 F. A design temperature of 850 F ±20 °F would be necessary.
- Based on the fuel quality presented a catalyst pitch of 7.4 mm or greater should be used. Fly ash angles entering the catalyst should be maintained approximately within ±15° from vertical. Sootblowers are recommended in this circumstance to maintain catalyst cleanliness.
- High carbon ash would carry the risk of increasing the pluggage of catalyst and possible result in a fire within the catalyst. Unburned carbon should be limited to less than approximately 15% to minimize the chance for pluggage and fire. Any catalyst that has a fire will be permanently destroyed due to sintering.
- Large particle ash (LPA) must be controlled prior to the catalyst. LPA escaping capture will cause pluggage of the catalyst.
- Ammonia should not be injected below minimum operating temperatures (MOT). Based on the SO2 and SO3 reported the MOT would be approximately 600 F. For lower sulfur fuels and/or reduced NOx removal performance a lower MOT would be possible. Additionally, brief periods of operation below the MOT would be possible without permanent degradation. In no event would any ammonia be allowed to be injected below 530 F for any likely combination of reasonable sulfur and NOx removal parameters. The NOx reduction for a reduced MOT should be considered in 30-day rolling average scenarios. Minimum flue gas temperatures listed for Units 1 and 2 are well below this threshold.
- Due to the high sodium and iron concentrations it is recommended that a full SCR bypass system be installed. During lay-up periods the catalyst would need to remain warm and dry (above condensing conditions), for instance with an air drying or

dehumidification system. This may necessitate the use of a dehumidifier and air lock system to access the reactor.

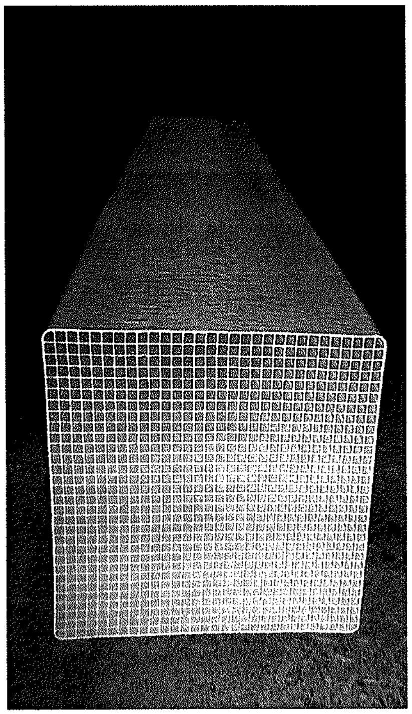
- Molar ratio NH3/NOx distribution ± 10% absolute.
- Gas velocity distribution ± 15% absolute.

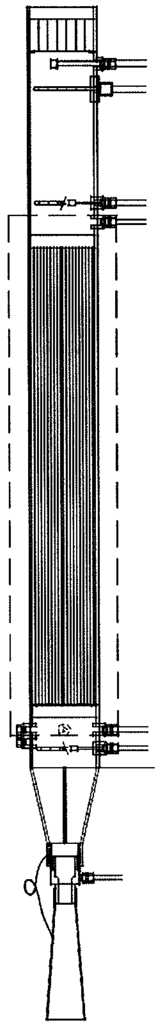
I would like to note that in CERAM's catalyst production history dating from 1985 and concerning more than 350 deliveries we have never had a guarantee or warrantee claim. We certainly want to maintain this record of success. However, based on the information provided as well as our large foundation of work related to the fuel considerations noted in the query and study CERAM can provide a commercial offering regarding this project. However, considering some of the remaining uncertainties we would recommend further testing to ensure a successful result. We agree that it would be beneficial to jointly explore common concerns to ensure that any full scale application would be a success. Please advise if we could be of help to further develop a test plan or answer any questions.

Best Regards,
John Cochran

CERAM Environmental, Inc.
www.frauenthal.net
913.239.9896 (phone)
913.205.5615 (cell)

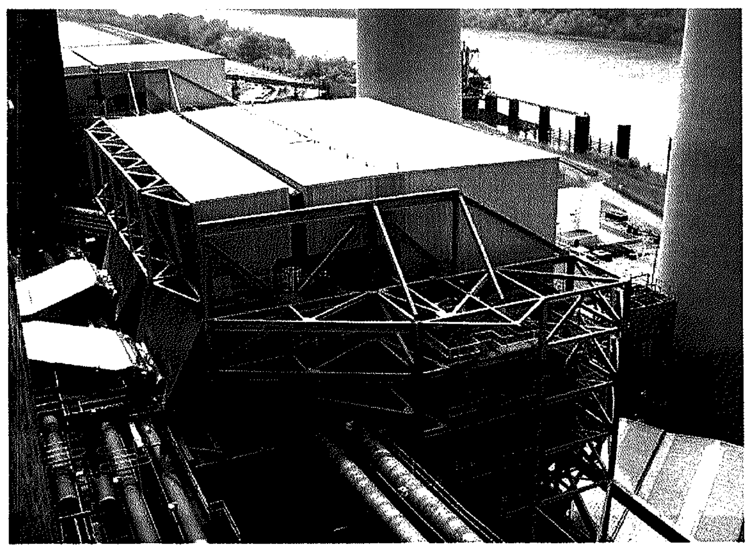
CERAM's CoPilot® Catalyst Test Reactor

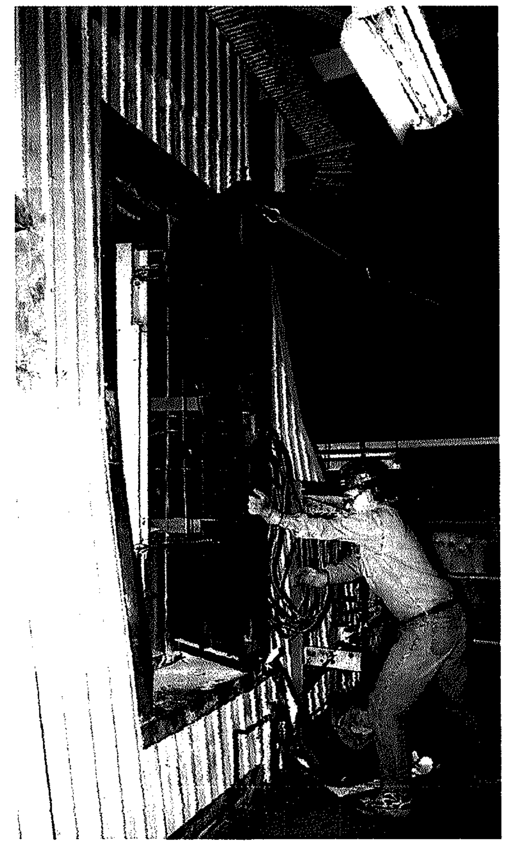




CERAM

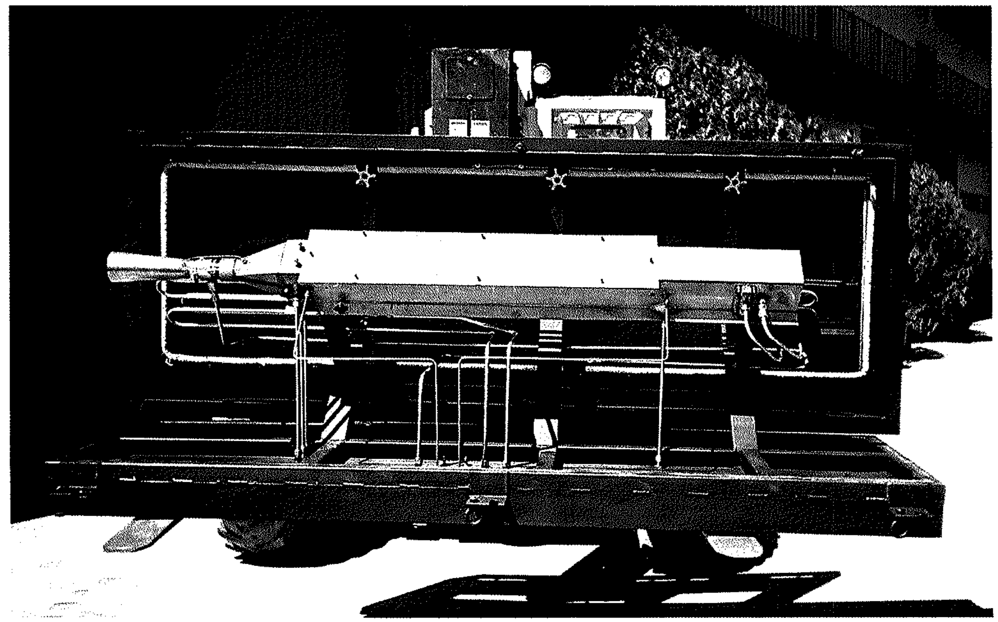
ENVIRONMENTAL, INC.





CoPilot® Catalyst Test Reactor

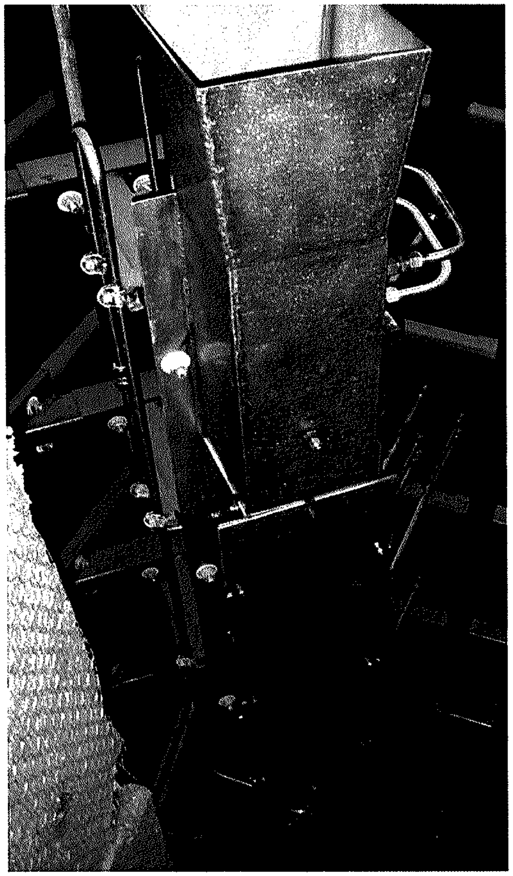
- Patented In-Situ Self Contained Catalyst Testing Apparatus
- In-Situ Reactor Allows for Catalyst Exposure to Actual Flue Gas Conditions Present
  - Fly Ash
  - Flue Gas Constituents
  - Temperature
- Allows Modulation of Gas Flow Velocity to Match SCR Reactor Conditions
- Allows On-Line Access to Test Elements – No Outage Required for Access
- Proven on 8 References



CoPilot® Catalyst Test Reactor

CERAM ENVIRONMENTAL, INC.

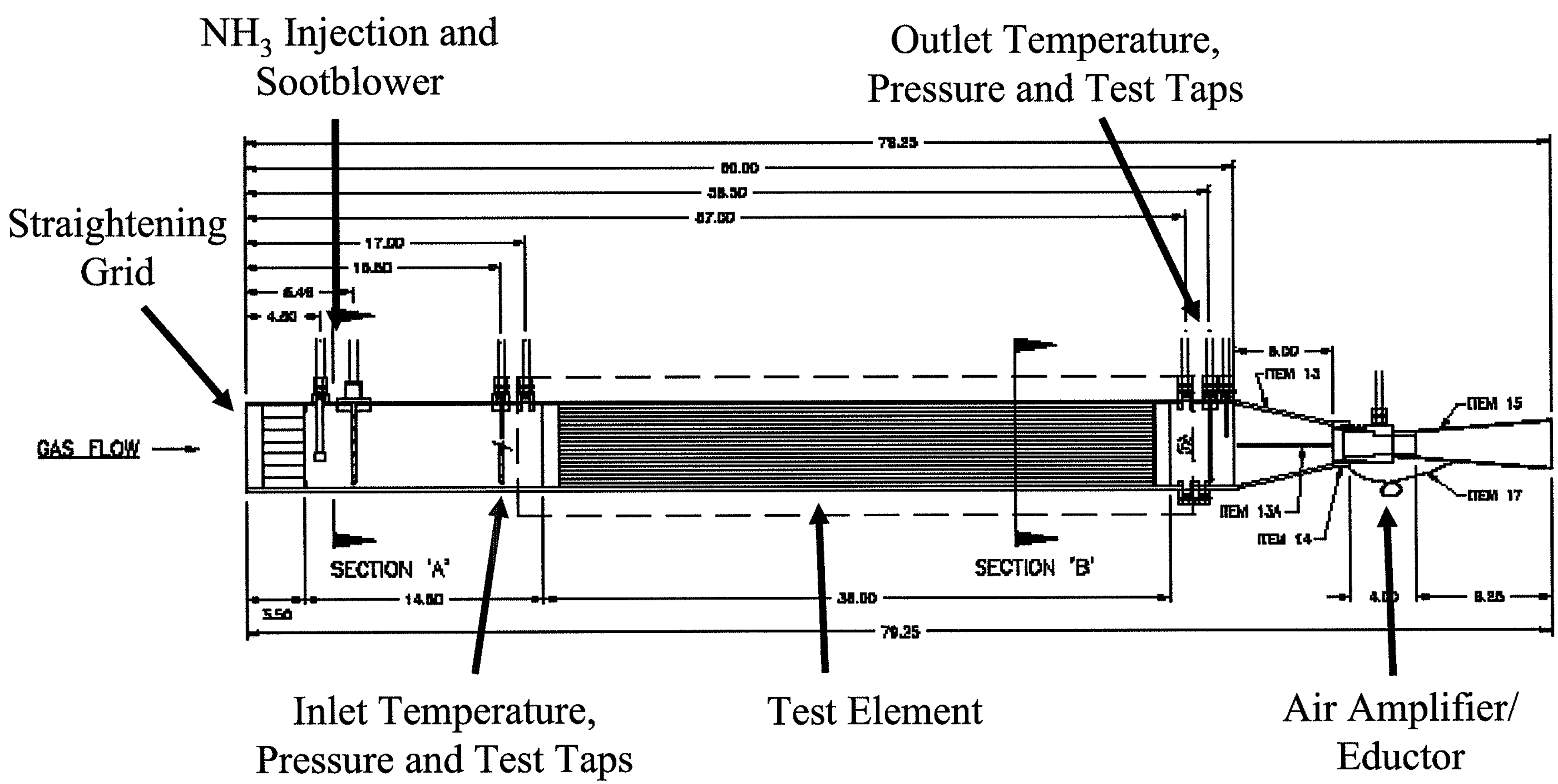
CoPilot® Catalyst Test Reactor



- Can House Honeycomb, Plate, or Fiber Based Catalyst Elements (6” x 6” x 38” long)
- Venturi Flow Inductor for Control of Flue Gas Velocity to Match SCR Reactor Conditions
- Includes Sootblower and LPA Screen to Maintain Catalyst Cleanliness
- Temperature, Pressure, and Inlet/Outlet Sampling Taps for On-Line Monitoring
- Allows for On-Line NOx Measurement
- Provisions for NH_3 Injection to Fully Replicate Reactor Conditions

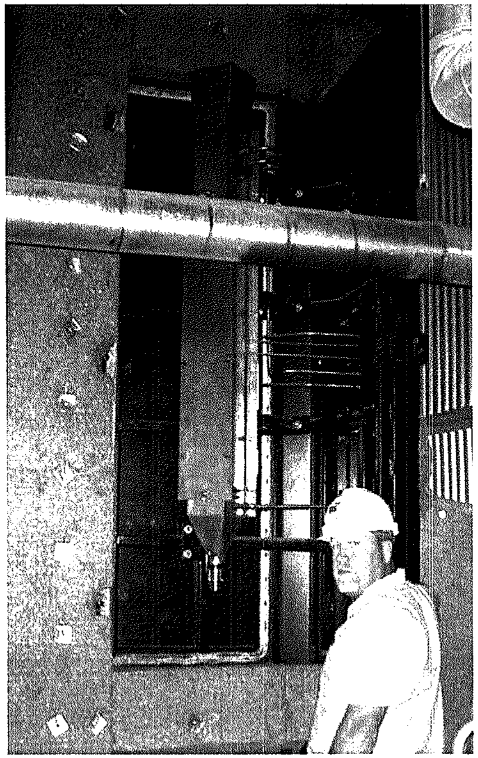
CERAM ENVIRONMENTAL, INC.

CoPilot® Catalyst Test Reactor



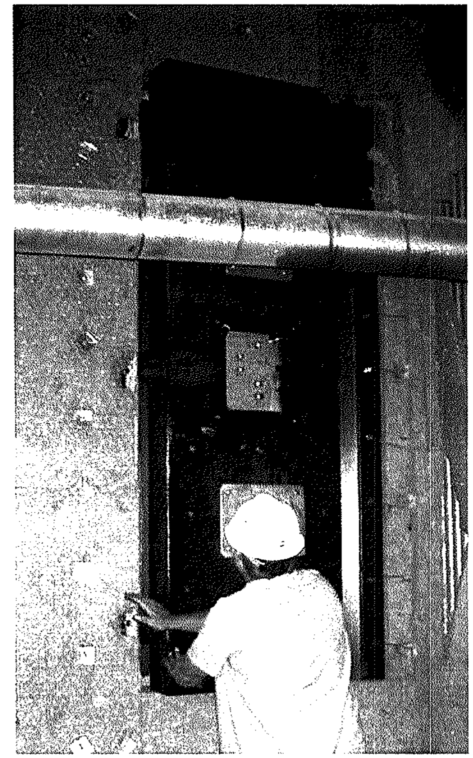
CERAM ENVIRONMENTAL, INC.

Door Operation



1. Open Door

2. Remove/Install Element

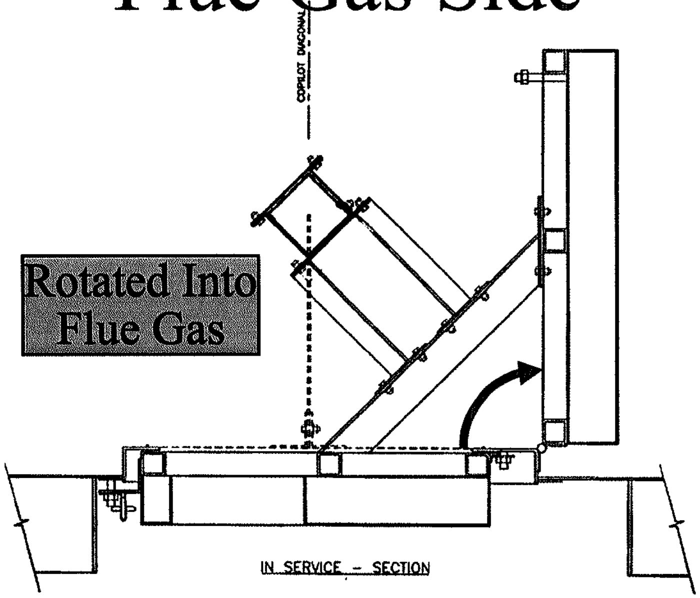


3. Close Door

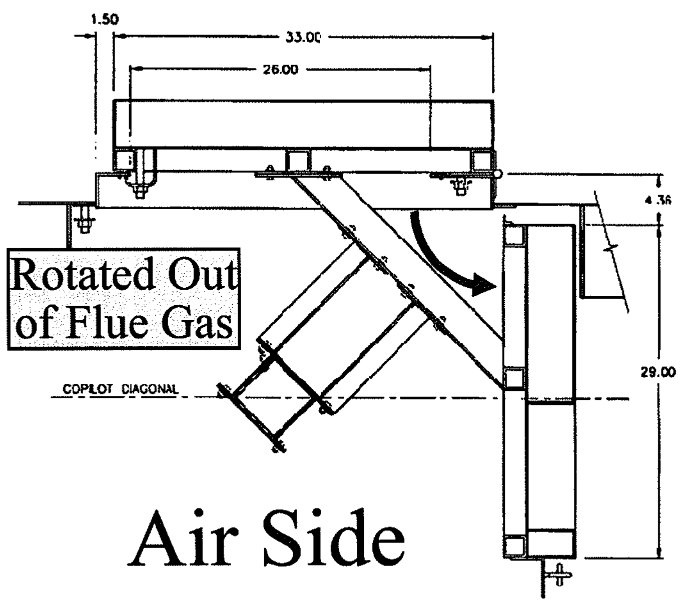
CERAM ENVIRONMENTAL, INC.

CoPilot® Door Action

Flue Gas Side



Allows for Catalyst Test Element Removal Without Unit Outage

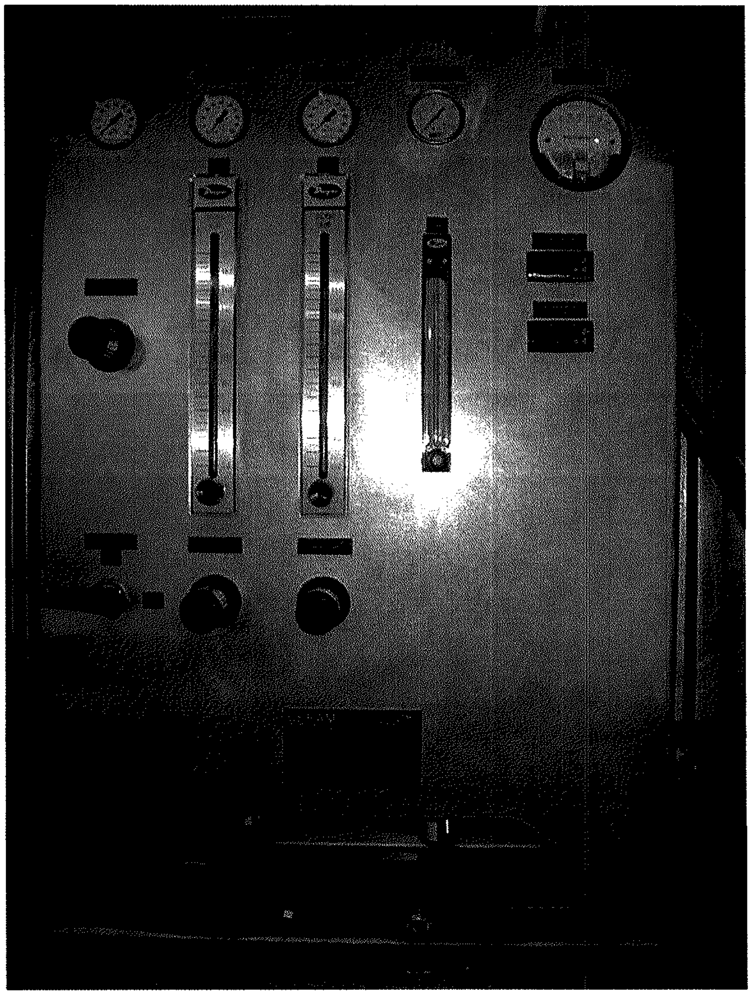


Air Side

OUT OF SERVICE - SECTION

CERAM ENVIRONMENTAL, INC.

Instrument Panel



- Regulates Flue Gas Flow Through Test Reactor
- Interface for Sootblowing
- Monitor Pressure Drop and Temperature
- Ammonia Injection Flow Control (if required)
- Main Supply Air Shut Off

CERAM ENVIRONMENTAL, INC.

CoPilot® Uses and Advantages

- Allows Assessment of Process Feasibility for New Application Types
- Allows Accurate Assessment of Impacts on SCR Catalyst from Existing Fuels and Plant Operations
- Minimizes Chances for Surprises Prior to Initial Operation
  - Excessive Catalyst Deactivation
  - Large Particle Ash
  - High LOI

Fuels Assessment

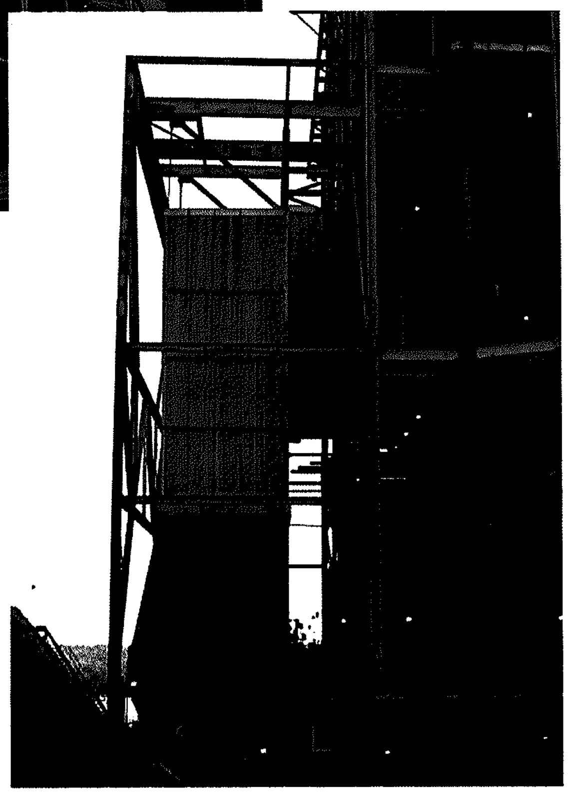
- Determine SCR Catalyst Impacts of Specific Fuels
  - Highly Erosive Ash (Catalyst Mechanical Durability, Wall Thickness)
  - High Ash Loadings (Catalyst Pitch Selection)
  - Determine Impacts of Challenging Fuels (Catalyst Deactivation and Oxidation Rates)

CERAM ENVIRONMENTAL, INC.

Year-Round Catalyst Management

- Annual Catalyst Sample Testing is Recommended
- Year-Round SCR Operation will Limit the Opportunity to Remove Catalyst Samples for Testing
- CoPilot® Provides On-line Access to Catalyst Samples Exposed to Real Flue Gas Conditions
- Will Allow "Anytime" Access to Elements for Annual Catalyst Testing for Units With 2 to 3 Year Outage Intervals

CoPilot® Installation Locations



- Preferred Location: Long Vertical Downward Section of Duct Downstream of Economizer
- Ash Exposure Important Component of Simulating SCR Application
  - Representative Pluggage Risk
  - Ash Abrasion Effect on Catalyst
  - Catalyst Absorption of Catalyst Poisons

CERAM ENVIRONMENTAL, INC.

Installation

- Required Duct Opening of Approximately 36 x 101 inches
- Lift CoPilot® Into Place and Weld Frame to Duct Wall
- Install Instrument Panel on Floor/Grating/Handrail in Vicinity of the CoPilot®
- Connect Air Supply, Eductor Air, Sootblower Air, Differential Pressure Lines, and Ammonia (if applicable)
- Install Thermocouples
- Install Catalyst Test Element and Seal to Prevent Leakage

CERAM Can Provide Full Installation Support

CERAM ENVIRONMENTAL, INC.

-----Original Message-----
From: Blakley, Robert [mailto:rblakley@burnsmcd.com]
Sent: Wednesday, April 18, 2007 4:52 PM
To: Pritchard, Scot G.
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

Scot,

On behalf of Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative (Minnkota), Burns & McDonnell (B&McD) is exploring the willingness of Selective Catalytic Reduction (SCR) vendors to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at Milton R. Young Station (MRYS). Minnkota's Unit 1 and Square Butte Electric Cooperative's Unit 2 each fire 100% North Dakota lignite using cyclone furnaces in subcritical boilers.

Burns & McDonnell requests Cormetech to review the attached request document and respond within three weeks if possible. If Cormetech's response is expected to extend beyond the timeframe requested, please advise with an estimated date when such a response could be provided.

<MRY SCR Vendor Query (4-18-07 final).doc>

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
Project Engineer
Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: Blakley, Robert
Sent: Tuesday, June 26, 2007 3:28 PM
To: 'Pritchard, Scot G.'
Cc: Rutherford, Scott J.; Freeman, Jeremy T.
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Scot -

We have not been favored with a final response from Cormetech on this request. We want to inform Minnkota about the timing of when Cormetech expects to reply. They have been asked by the NDDH for the vendor's responses.

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
Project Engineer
Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: Pritchard, Scot G. [mailto:PritchardSG@Cormetech.com]
Sent: Monday, May 14, 2007 11:00 PM
To: Blakley, Robert
Cc: Rutherford, Scott J.; Freeman, Jeremy T.
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Robert,

Thank you for the inquiry and opportunity to discuss the the subject opportunity. We have started the review process, however we will require additional time to provide our comments and any related questions back to you. At this time we expect that we will be bale to submit initial information at the end of the month.

Please acknowledge receipt and let us know if any additional relevant information has become available on the subject project to date.

Thank you and regards,

Scot Pritchard
VP, Sales & Marketing
Cormetech
919-595-8708 o
919-815-2380 c

From: Blakley, Robert
Sent: Wednesday, April 18, 2007 3:54 PM
To: 'fgh@topsoe.com'
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

Flemming,

On behalf of Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative (Minnkota), Burns & McDonnell (B&McD) is exploring the willingness of Selective Catalytic Reduction (SCR) vendors to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at Milton R. Young Station (MRYS). Minnkota's Unit 1 and Square Butte Electric Cooperative's Unit 2 each fire 100% North Dakota lignite using cyclone furnaces in subcritical boilers.

Burns & McDonnell requests Haldor Topsoe to review the attached request document and respond within three weeks if possible. If Haldor Topsoe 's response is expected to extend beyond the timeframe requested, please advise with an estimated date when such a response could be provided.

<MRY SCR Vendor Query (4-18-07 final).doc>

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
Project Engineer
Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: Wayne Jones [mailto:WSJ@topsoe.com]
Sent: Thursday, May 10, 2007 10:24 AM
To: Blakley, Robert
Subject: HTI: Comments to SCR Technology at MRYS Units 1&2

Bob,

Haldor Topsoe has reviewed in detail the information and data sent regarding the viability of SCR technology on the Milton R. Young Station (MRYS) Units 1&2. We believe that two separate issues exist with this application. First are the extremely high flue gas exit temperatures (FGET) and lack of flue gas temperature control over the long term and second are the fuel related issues specific to this variety of North Dakota lignite. Since high (FGET) is a unit specific problem we are not going to address this issue. We will however address the North Dakota lignite fuel that is burned at MRYS.

Based on the fuel and ash analysis that was provided, we estimate that the deactivation rate of the catalyst will be high but manageable. We expect a deactivation rate in line with wood fired boilers which have been successfully fitted with SCR. We also expect the deactivation rate to be steep initially but to flatten out considerably after about 4000 hours.

The expected poisons are mostly soluble, therefore periodic water washing of the catalyst can be used to regain activity and to increase overall service life. This technique is used on many wood and some PRB fired applications.

Based on the fuel analysis provided to HT and assuming that FGET can be controlled HT would be willing to guarantee SCR catalyst performance on these units.

Regards,
Wayne

Wayne S. Jones
Account Manager, SCR Catalyst & Technology
Haldor Topsoe, Inc.
281-228-5136 (office)
281-228-5129 (fax)
281-684-8811 (cell)
wsj@topsoe.com
www.HaldorTopsoe.com

From: Blakley, Robert
Sent: Monday, April 28, 2008 3:57 PM
To: 'fgh@topsoe.com'
Cc: 'Wayne Jones'
Subject: RE: Comments to SCR Technology at MRYS Units 1&2

Flemming -

We would like Haldor Topsoe to comment on this question: if Haldor Topsoe were asked to provide a catalyst performance and service life guarantee and replacement warranty, whether a minimum operating time that Haldor Topsoe would propose would be based on the special nature of this fuel and ash composition method of firing (in a cyclone) and the location relative to gas cleaning equipment. As mentioned during our telephone conference, the April 2007 SCR vendor query contained evidence of fine sodium particles downstream of MRY Station Unit 2's cold-side ESP and wet FGD scrubber.

We are also interested in learning more about the basis of statements mentioned in the May 10, 2007 response of the 4,000 hours as a suggested number of operating hours for the initially steep but tapering catalyst deactivation rate. It would be good to note in the response to the above questions whether Haldor Topsoe would require additional SCR catalyst coupons or slip-stream pilot testing with laboratory analysis in order to be confident in their proposed catalyst selection, design, and performance and service life guarantees.

It would be beneficial to reference Haldor Topsoe's previous May 10, 2007 response when sending a supplemental response addressing this subject and issues raised in our 4/24/08 discussion.

Bob Blakley
Burns & McDonnell
(816) 822-3842

From: Blakley, Robert
Sent: Monday, April 28, 2008 8:54 AM
To: 'fgh@topsoe.com'
Cc: 'Wayne Jones'
Subject: RE: Comments to SCR Technology at MRYS Units 1&2

Flemming -

Thank you for discussing the issues of SCR feasibility involving North Dakota lignite-fired cyclone boilers.

Hopefully you've gotten a chance to review the April 18, 2007 query, and pilot SCR testing performed at Coyote Station, on a boiler of the same size, cyclones and similar fuel as fired at Milton R. Young Station's Unit 2 boiler.

We would appreciate an email response to this followup, with discussion of the technical research and experience basis of Haldor Topsoe's positions on catalyst fouling, poisoning, and blinding appropriate to high sodium, medium sulfur coal flyash and flue gas produced from these boilers. We are interested in learning more about the experience you mentioned about washing of catalyst fouled with high sodium alkalis that was ineffective at restoring catalyst activity.

We are also interested in knowing more about Haldor Topsoe's willingness to offer performance guarantees, and what that would include from a commercial standpoint along with a catalyst warranty. Of particular interest is whether Haldor Topsoe's guarantee would satisfy a "make good" requirement, require full-scale field testing of each boiler prior to catalyst selection and design, testing catalyst in a slipstream arrangement or other exposure demonstrations, and if there are any other qualifiers beyond the assumption that the high flue gas temperatures in a conventional hot-side, high-dust SCR were limited by a solution developed by others.

We realize that this is a concentrated effort that does not allow much time to review and provide such responses.

We ask that Haldor Topsoe provide their email response by Monday, 5/5 12 pm (noon), so that we can review this and forward to Minnkota.

Again, thank you for your attention to this matter.

Bob Blakley
Burns & McDonnell
(816) 822-3842

From: Flemming Hansen [mailto:FGH@topsoe.com]
Sent: Monday, May 05, 2008 1:42 PM
To: Blakley, Robert
Cc: Wayne Jones; jmj@topsoe.dk; hajh@topsoe.dk; trs@topsoe.dk
Subject: RE: Comments to SCR Technology at MRYS Units 1&2

Bob,

We have reviewed the design basis and experience on ND lignite.

Our general conclusion was that the deactivation rate is probably going to be at the high in the initial 10,000 hours. Somewhat longer than the 4,000 hours stated earlier. The deactivation rate will be tapering off as the catalyst ages. We expect the catalyst to loos about 60% of its initial activity over the first 10,000 operating hours. This deactivation rate is higher than what we have seen for wood fired boilers.

The number is based on the following assumptions:

1) Alkali content is at the same order as it is found in a wood fly ash.

2) The fly ash load is 5 to 10 times higher than it is seen in wood fired boilers which means that the deactivation should be 5 -10 higher with ND lignite with the assumption that the fraction of alkali aerosol that is captured in the catalyst is constant (this is not the case, cf. 3).

3) The fly ash size distribution of North Dakota lignite is broader compared to wood fly ash, which is an advantage since the attrition of the catalyst surface is higher. However, the attrition effect is not as high as in most coal fired applications since cyclone fired boilers are typically used in ND lignite fired boilers. The carry over of coarse fly ash from the furnace is much lower in cyclone fired boilers. All together we expect that the effect of fly ash distribution compensates for the higher fly ash load compared to a wood fired boiler.

3) The effect of sulfur in the flue gas adds to the deactivation rate compared to typical wood firing. SO_2 levels in ND lignite flue gas are 700-800 ppm whereas it is <10 ppm in wood flue gas. The sulfur leads to a strengthening and densification of the blinding layers that originates from deposition of Ca, Na, K aerosols.

Besides the deactivation there is a clogging issue. At the Coyote station test this was the primary concern/experience. It is well known that soot blowing is difficult in pilot scale due to edge effects but also due to the dimensions of the soot blower tubes (max about 1/2"). Orifices have to be smaller compared to full scale in order to distribute the soot blower air. As a consequence the soot blower should be moved closer to the catalyst in order to obtain the same dynamic pressure at the catalyst surface which makes it difficult to actually cover the entire catalyst surface. We suggest that the next step is a larger pilot scale experiment with in the order of 2x2m of catalyst installed. We would like to participate in such an experiment. This would allow better catalyst cleaning and give a better determination of the catalyst degradation over time.

Based on our current information we expect 60% deactivation over the first 10,000 operating hours.
We can not provide a "make good" guarantee, but are willing to warrant the catalyst performance up to the contract value.

I trust the above will be helpful in your design of SCRs for this type of application.

Flemming G. Hansen
Manager SCR DeNOx Catalyst
Haldor Topsoe, Inc.
281-228-5120 (office)
281-228-5129 (fax)
281-684-8820 (cell)
FGH@Topsoe.com
www.topsoe.com

From: Blakley, Robert
Sent: Monday, May 05, 2008 5:44 PM
To: 'Flemming Hansen'
Cc: Wayne Jones; jmj@topsoe.dk; hajh@topsoe.dk; trs@topsoe.dk
Subject: RE: Comments to SCR Technology at MRYS Units 1&2

Flemming -

We have reviewed your response to our followup to the query, and had some clarifications:

Do we understand your meaning correctly in item 1 of your email that due to the increased flyash loading for a hot-side, high-dust SCR application at MRY Station, Haldor Topsoe thinks the deactivation rate will be 5-10 percent higher than what is typically seen in wood-fired boiler SCR applications?

The meaning of the attrition effect is not readily understood. We are not sure if you are referring to erosion or gross pluggage of the catalyst gas passages from the flyash particles.
Can you provide some additional explanation?

The expected impact of sulfur on the catalyst deactivation rate compared to wood firing was not provided, as was given for the higher flyash loading. It would seem to be a much more significant impact if it is at all related to the gross difference in sulfur concentration (70-80 times more sulfur on a volume basis).
Can you provide some additional explanation of the expected impact of sulfur on the catalyst deactivation rate compared to wood firing, especially given that the Coyote pilot SCR test catalyst pores were completely filled with sodium and potassium-sulfate compounds.

We also assume that the comments about sootblowing and clogging of catalyst with flyash relate to the impact largely as an issue of avoiding gross flow channeling or maldistribution that would make some sections of the catalyst non-effective, assuming that the pores were otherwise not blinded or plugged?

We would appreciate any immediate reply to these questions, so that we can forward these to Minnkota.

Bob Blakley
Burns & McDonnell
(816) 822-3842

From: Joakim Reimer Thøgersen [mailto:jmj@topsoe.dk]
Sent: Wednesday, May 07, 2008 8:09 AM
To: Blakley, Robert
Cc: Wayne Jones; jmj@topsoe.dk; hajh@topsoe.dk; trs@topsoe.dk
Subject: Re: FW: Comments to SCR Technology at MRYS Units 1&2

Bob,

Some answers to your questions/comments:

Do we understand your meaning correctly in item 1 of your email that due to the increased flyash loading for a hot-side, high-dust SCR application at MRY Station, Haldor Topsoe thinks the deactivation rate will be 5-10 percent higher than what is typically seen in wood-fired boiler SCR applications?

No we don't think the the deactivation is 5-10 times higher. The alkali concentration in the fly ash is similar. The fly ash concentration is 5-10 times higher i lignite flue gas. But the fraction of flue alkali alkali that deposits in the catalyst is much smaller in lignite flue gas. The reason is that part of the alkali ihe furnace is bound in coarse aluminum/silicate fly ash that don't to the same extent deposits in the catalyst. When the alkali is incorporated in aluminum/silicate fly ash the alkali also becomes inactive as a SCR poison. The lignite fly ash also has a cleaning effect by attrition of the surface that causes re-entrainment of particle deposits.

The meaning of the attrition effect is not readily understood. We are not sure if you are referring to erosion or gross pluggage of the catalyst gas passages from the flyash particles.
Can you provide some additional explanation?

Re-entrainment or cleaning of the catalyst surface by particle impaction

The expected impact of sulfur on the catalyst deactivation rate compared to wood firing was not provided, as was given for the higher flyash loading. It would seem to be a much more significant impact if it is at all related to the gross difference in sulfur concentration (70-80 times more sulfur on a volume basis).
Can you provide some additional explanation of the expected impact of sulfur on the catalyst deactivation rate compared to wood firing, especially given that the Coyote pilot SCR test catalyst pores were completely filled with sodium and potassium-sulfate compounds.

The sulfur reacts with deposited NaCl, CaO, KCl which means that the particles swell and the blinding layer becomes more impermeable.

We also assume that the comments about sootblowing and clogging of catalyst with flyash relate to the impact largely as an issue of avoiding gross flow channeling or maldistribution that would make some sections of the catalyst non-effective, assuming that the pores were otherwise not blinded or plugged? Exactly.

Our predictions are somewhat semi quantitative since the predictions are based on extrapolation/interpolation from wood firing and PRB fired boilers. I hope these clarifications are sufficient. Otherwise you can call me (+45) 22754374.

Best Regards, Joakim

From: Blakley, Robert [mailto:rblakley@burnsmcd.com]
Sent: Wednesday, April 18, 2007 4:55 PM
To: Anthony C. Favale
Subject: Request for Lignite SCR Feasibility Commercial and Technical Information

Tony,

On behalf of Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative (Minnkota), Burns & McDonnell (B&McD) is exploring the willingness of Selective Catalytic Reduction (SCR) vendors to offer guarantees for high-dust SCRs and catalyst with respect to NO_x emissions reduction performance at Milton R. Young Station (MRYS). Minnkota's Unit 1 and Square Butte Electric Cooperative's Unit 2 each fire 100% North Dakota lignite using cyclone furnaces in subcritical boilers.

Burns & McDonnell requests Hitachi to review the attached request document and respond within three weeks if possible. If Hitachi's response is expected to extend beyond the timeframe requested, please advise with an estimated date when such a response could be provided.

<MRY SCR Vendor Query (4-18-07 final).doc>

We appreciate your cooperation in this matter.

Sincerely,

Robert D. Blakley, P.E.
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Plant Services Department
Burns & McDonnell
(816) 822-3842
rblakley@burnsmcd.com

From: Anthony C. Favale [mailto:Anthony.Favale@hal.hitachi.com]
Sent: Friday, May 11, 2007 1:53 PM
To: Blakley, Robert
Cc: David Paz; David J. Brozek; Stephen Guglielmo; Masayuki Hirano; Isato Morita; Jennine Eickmeyer
Subject: RE: Request for Lignite SCR Feasibility Commercial and Technical Information

Robert,
As you know there has been very little testing and data available in North Dakota lignite. Hitachi has reviewed this data and we have the following comments:
1. Basically, it is quite difficult to install and operate the SCR at temperature over 850F. If there is no plan to reduce the flue gas temperature, the catalyst will deactivate very quickly above 850F.
2. The ash tables show the Na content as very high. It may cause serious deactivation of the catalyst.
3. Also, SO3 content in ash is very high. This means that there is Sulfur compounds in addition to the oxides. It may also cause faster catalyst deactivation.
4. There is also a concern over how sticky the ash is and if this will cause a pluggage problem.
Whit all these unknowns we strongly recommend that a slipstream test be performed to confirm the applicability of the catalyst for this flue gas.

Please advise if you have any comments,

Best Regards,

Tony Favale

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